Performance steering and front suspension of the car

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Abstract. The article contains the research results aimed at reliable performance of the front suspension and the steering system of the car in operation. The main malfunctions of these systems were detected (bus LiAZ-5256 was selected as the object of research) and their influence on "withdrawal" from the specified movement trajectory was identified. The set of diagnostic parameters was substantiated for the assessment of the technical condition of these systems and their standard values, which were the necessary components to provide the function ability of these systems. The search and the fault recovery algorithm in steering system and front suspension of the car were offered.

1. Introduction

The analysis of the reasons high accident rate of road transport in Russia shows that from 15 to 20% [1] of the total number of road traffic accidents accounted for the technical malfunctions of vehicles. Statistics show that the number of accidents for this reason steadily increases from year to year. According to the State Traffic Inspectorate, for example, the number of accidents caused by technical malfunctions of cars for 2017 is up to 18, 5% [2] compared to the same period in 2016.

A special danger is caused by the operation of cars with faulty systems that directly influence their active security, because the refusals of these systems lead to the most serious consequences of road accidents. The steering system and the front suspension of the car [3,4] refer to such systems as brake system, wheels and tires. The steering system and front suspension belong to the systems providing its stability and controllability and directly influence on the road safety. Their maintaining in a technically serviceable condition during the entire resource run of the car is one of the most important conditions for reducing accidents on the roads.

There are different malfunctions during the operation on the structural elements of the steering and suspension, the main reasons for which are the wear process and deformation of their parts under the influence of static and dynamic workloads. As a result, there are irreversible offsets and backlash in pivot nodes, ball joints, bearings, the toothed gearing of the steering mechanism and angle reducer power steering, which cause the "withdrawal" of the car from a given trajectory.

The studies aimed at ensuring reliable operation of the steering system and the front suspension were carried out in the real operating conditions of buses LiAZ-5256, selected as the object of study. The bus of this model is widely used in different regions of the country and enjoys steady demand until the present.

The normative documents regulating technical maintenance and repair of the considered systems [5-8] propose as the diagnostic parameters for assessment of their technical condition the total backlash in the steering, the force on the steering wheel and the convergence of front wheels. But to identify and
localize the specific malfunctions in components of the front suspension and the steering with the help only these parameters in practice is rather difficult. It's necessary to have the set of diagnostic parameters with their normative values, with the sufficient degree of accuracy and reliability assessing the technical condition of all elements included in the front suspension and the steering of the car.

2. Methods and Materials
The research made at the Department of «Automotive transport» of the Vladimir State University allows to form such complex for the bus LiAZ-5256, which includes:

- the withdrawal of the car from the given trajectory of movement \( Y, \text{m/km} \);
- the total backlash in the steering system – \( \alpha, \text{deg.} \);
- the convergence of the front wheels – \( \beta, \text{mm} \);
- the misalignment of the front axle relative to the vehicle body–\( \gamma_f, \text{mm} \);
- the misalignment of the rear axle–\( \gamma_r, \text{mm} \);
- the force on the steering wheel –\( F, \text{N} \);

As a complex indicator that most characterizes the technical condition of the front suspension and the steering is taken "withdrawal" of the bus which allows evaluating quantitatively the deviation of its motion from a given trajectory of movement. The "withdrawal" is formed from the backlashes in the steering gear, the angle reducer, the steering gear, the wheel bearings, the power steering, which arise because of irreversible shifts in the hinge joints as well as the wear of tapered roller bearings.

In general, the dependence of the influence of diagnostic parameters on the bus withdrawal in coded form can be expressed with the help of the regression equation:

\[
y = b_1x_1 + b_2x_2 + \ldots + b_nx_n = \sum_{i=1}^{k} b_ix_i,
\]

where \( y \) is the response function in coded form (the withdrawal of the bus characterizing its stability and controllability); \( k \) is the number of selected parameters as the result of ranking; \( b_i \) is the model coefficients (weight characteristics) that take into account the degree of influence \( i \) parameter on the response function; \( x_i \) is the coded values of the \( i \) parameter.

The numerical values of the encoded parameters \( (x_1, x_2, \ldots, x_k) \) and the coefficients \( (b_1, b_2, \ldots, b_n) \), by which you can judge about the amount of influence of each of them on the response function, calculated by the method of planning of the experiment. The final form of the regression equation after its checking on the adequacy with the help of Fisher criterion is:

\[
Y = 1.90\alpha + 1.53\beta + 2.18\gamma_f + 0.65\gamma_r - 19.97.
\]
of the steering and the front suspension of the car. The results of experimental data are in table 1 and in the form of differential \( f(Y) \) and integral \( F(Y) \) distribution functions of the “withdrawal” in figure 1.

### Table 1. The results of measurements of buses “withdrawal”

| Interval                  | 1-st | 2-nd | 3-d | 4-th | 5-th | 6-th | 7-th |
|---------------------------|------|------|-----|------|------|------|------|
| The borders of intervals, m | 0–2  | 2–4  | 4–6 | 6–8  | 8–10 | 10–12| 12–14|
| The middles of intervals, m | 1    | 3    | 5   | 7    | 9    | 11   | 13   |
| The experienced frequencies, \( m_i \) | 2    | 11   | 20  | 21   | 3    | 2    | 1    |
| The relative experienced frequencies, \( s_{m_i} \) | 0.03 | 0.18 | 0.33| 0.35 | 0.05 | 0.03 | 0.017|
| The mean square deviation, \( \sigma \) | 2.30 |      |     |      |      |      |      |
| The coefficient of variation, \( \nu \) | 0.40 |      |     |      |      |      |      |
| The average value of “withdrawal”, \( Y_{av} \), m | 5.73 |      |     |      |      |      |      |

![Figure 1. The distribution of “withdrawal” values of buses: 1— the histogram; 2, 3 – the differential and the integral distribution functions.](image)

By analogy with the method adopted in the theory of reliability, the area of dispersion of values of diagnostic parameter to limit with borders corresponding to the required level of probability of uptime [11]. For critical systems, which include the front suspension and the steering, we can use the limit distribution of diagnostic parameter \( Y \) by the probability level \( P = 0.85 \).

In practice with a relatively small error in determining the limit diagnostic standards we can use the method of addition to the found average parameter value \( Y_{av} \), one or one and a half value of standard deviation \( \sigma \). The limit standard of “withdrawal” of bus \( Y_f \), directly affecting the traffic safety and bounded by the probability level \( P = 0.85 \), is given by [12]:

\[
Y_f = Y_{av} + \sigma = 5.73 + 2.30 \approx 8 \text{ m.}
\]  

(3)
The same value of “withdrawal” can be found by constructing an integral function of its distribution \( F(t) \) by operating time (figure 1). When reaching the limit value of “withdrawal” the driver begins to feel the significant difficulties in bus driving [12-14], stability of the bus is broken, increasing tire wear, fuel consumption etc.

3. Results and discussion

Valid values of diagnostic parameters, which provide the necessary level of the vehicle uptime at a given operating time, we can find by the regularities of their changes in operating time. In this work, the theoretical curve of parameter change dependence \( Y \) in the meantime \( t \), found as the results of processing the experimental data using the Microsoft Excel program, has the following form:

\[
Y = Y_n + vt^\alpha = 0.7 + 0.0002 \cdot t^{1.0},
\]

(4)

where \( t \) is the operating time of the bus, km; \( Y_n = 0.7 \) m/km is the nominal (initial) value of “withdrawal”; \( v=0.00018 \) m/km is the intensity of changes of the parameter \( Y \) in operating time; \( \alpha = 1.0 \) is the indicator degree that determines the nature and the dependence degree of parameter \( Y \) on the operating time \( t \).

With the known frequency of diagnosis \( (t_d = 10000 \) km), the found values of the limit standard \( Y_f = 8.0 \) m and the change intensity of bus “withdrawal” of on operating time \( v = 0.00018 \) m/km, the value of acceptable standard \( Y_d \) have the following form:

\[
Y_d = v \left( \frac{\sqrt{Y_f}}{v} - t_d \right) = 0.00018 \left( \sqrt{8 \cdot \frac{1}{0.00018}} - 10000 \right) = 6.2 \text{ m}.
\]

(5)

The standard values of others diagnostic parameters for assessing the technical condition the front suspension and steering of the car which were found in the above-mentioned method, are summarized in table 2 [15].

| Parameter | Designation | Parameter value |
|-----------|-------------|----------------|
| The bus withdrawal | \( Y_n, \text{m/km} \) | 0.7 | 6.2 | 8.0 |
| The total backlash in steering system | \( \alpha, \text{deg} \) | 12 | 16 | 20 |
| The convergence of front wheels | \( \beta, \text{mm} \) | 4 | 6 | 8 |
| The offset of the front axle | \( y_f, \text{mm} \) | 0 | 6 | 14 |
| The offset of the rear axle | \( y_r, \text{mm} \) | 0 | 6 | 14 |

The obtained values of limit [16] and permissible standards of diagnostic parameters are the necessary elements in the system of function ability support of the car front suspension and the car steering during control and diagnostic operations. Standards deviation beyond limits is the cause for making decision on necessary technical influences (in-depth diagnosis operations, adjustments, repairs, etc.) [17-19]. The diagnosis of considered systems is made out in accordance with the developed algorithm, setting the rational sequence on identification and elimination of emerging damages during the operation (figure 2) [20-21].
4. Conclusion
In developed system of the providing operable condition of the steering system and the front suspension of the car to reduce the complexity of diagnosing their technical condition we can control at first one of the diagnostic parameters - the bus withdrawal. If its value does not exceed the permissible ($\gamma \leq 6.2$ m/km), the examined bus units are in good technical condition. Otherwise the bus systems influenced its stability, and controllability is checked: the position of the front and the rear axles relative to the car body, the convergence of front wheels and the total backlash in the steering.

The control and diagnostic, repair and adjustment operations allow preventing the cars exploitation with the faulty condition of systems providing traffic safety and significantly reducing the number of accidents on the roads.

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