International Journal of Advanced Logistics, Transport and Engineering
https://ijalte.alt.edu.kz/
ISSN Online: 2790-5829
DOI 10.52167/2790-5829
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Received on February 16, 2023; Received in revised form on February 21, 2023; Accepted on March 06, 2023

DOI 10.52167/2790-5829-2023-5-1-1-8

Yermek Baubekov, Gabit Bakyt
Academy of Logistics and Transport, Almaty, Kazakhstan
E-mail: g.bakyt@alt.edu.kz

ANALYSIS OF THE IMPACT OF DYNAMIC LOADS ON THE SUPERSTRUCTURES OF RAILWAY BRIDGES

Abstract. All the car accidents have huge economic and social problems. Revealing true accident reasons, fairness of the technical expertise upon car accident reconstruction is being a priority task. The result of the conducted research is experimental proof of additional factors influence to brake system response time. When conducting research measurements of the friction linings, braking force on front and rear axle are to be made. For the test a group of five technically sound vehicles with mileage from zero to thirty thousand km was selected. Experimental research of the brake systems operation was conducted at the production base of «Mega Motors Almaty» LLP and “Arystan-NLA” diagnostic center. Diagnostic equipment of BILANMATIC MULLER German firm was used for testing. Obtained measurement results such as: friction lining thickness, brake system response time with actual thickness of friction linings, force on brake pedal upon braking on front(rear) axle, brake force on front(rear) wheels allowed clearly understand that the rise time to maximum deceleration significantly influences the wear of the friction linings and the force amount on the brake pedal. More detailed understanding of the above-mentioned factors influences degree and their weightage on brake system response time can be the issue of further, more detailed research using approach probabilistic methods.

Keywords: braking system, accident, experimental method, operational factors, friction lining, braking force.

Introduction. The aim of conducted research is to obtain experimental evidence of the additional factors effect onto brake system response time, aiming to clarify estimated dependence being applied upon investigating and reconstructing vehicle accidents by traditional methods and to increase expertise quality [1].

Measurements of friction pads, braking power on to front and rear axles are required to be made.

Five pieces of technically sound transport means with the mileage range from 0 to 30000 km were prepared for the brake tests.

Technical characteristics of the transport means are shown in Table 1.

Braking mechanisms of the transport means under research are sound and have been preliminarily dried out. Vehicles tyres are clean, dry, having no greasing spots and tread depth at the center of the tread is not less than 1 mm. Transport means tyre pressure comply with the requirements, specified in the vehicles operating manual [2].

Toyota Camry vehicles were involved in the research.
Table 1 - Toyota Camry technical characteristics (XV50 2.5 AT)

<table>
<thead>
<tr>
<th>Engine, model, type</th>
<th>VVT-i, 4V; 2AR-FE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swept capacity, cm³</td>
<td>2500</td>
</tr>
<tr>
<td>Maximum power, kW (HP) upon rev. Per min</td>
<td>133 (181); 6000</td>
</tr>
<tr>
<td>Maximum torque, Нм, rpm</td>
<td>231, 4100</td>
</tr>
<tr>
<td>Type, number of gears</td>
<td>Automatic, six staged</td>
</tr>
<tr>
<td>Drive gear</td>
<td>Front</td>
</tr>
<tr>
<td>Front suspension</td>
<td>Individual, spring-mounted</td>
</tr>
<tr>
<td>Rear suspension</td>
<td>Dependent sprung</td>
</tr>
<tr>
<td>Wheel size</td>
<td>215/60 VR16</td>
</tr>
<tr>
<td>Tyre air pressure, atm</td>
<td>4.00</td>
</tr>
<tr>
<td>Maximum speed, km/h</td>
<td>210</td>
</tr>
<tr>
<td>Front brakes</td>
<td>Disc-shaped, vented</td>
</tr>
<tr>
<td>Rear brakes</td>
<td>Disc-shaped</td>
</tr>
<tr>
<td>Full mass, kg</td>
<td>2100</td>
</tr>
<tr>
<td>Curb weight, kg</td>
<td>1540</td>
</tr>
<tr>
<td>Handling capacity, kg</td>
<td>560</td>
</tr>
<tr>
<td>Maximum load on to front axle, kg</td>
<td>2100</td>
</tr>
<tr>
<td>Maximum load on to rear axle, kg</td>
<td>2400</td>
</tr>
<tr>
<td>Service time</td>
<td>20000 km or 12 months</td>
</tr>
</tbody>
</table>

**Materials and methods.**

Brake systems performance efficiency research was conducted at the production base of “Mega Motors Almaty” LLP and “Arystan-NLA” diagnostic center. Production base is equipped with diagnostic equipment of BILANMATIC MULLER 7700 German firm, that was used upon testing.

Type of roll booth is approved by technical and metrological characteristics, metrological secured upon delivery, operation and after repairs according to state accuracy chart [3].

Measurement complexes used for diagnostics of 7500, 7700, 8600, 1000, 10000 series BILANMATIC vehicle brake system and suspension is presented by central processor with program menu, display, and printing unit.

The complex consists of:
- a device for measuring braking force and checking transport means brakes efficiency;
- a device for dynamic measurement of wheel alignment sum angle;
- a device for shock-absorber diagnostics and measuring static stress on to vehicle axle;
- a device for measuring speedometers, taximeters and tachographs parameters.

A device designed for measuring braking force and checking transport means brake system efficiency is based on reciprocity principle.

The vehicle under test is being installed motionless, and “a road” is moving with a given speed.

The role of the road is played by two pairs of rollers on which the wheels of one axle of the vehicle are installed. Each pair of rollers is being rotated from motor-reducer and imitates vehicle motion with the given speed. Diagnostics of one axle wheels brakes- front or rear is being
performed simultaneously. Upon pressing brake pedal, braking moment of each wheel is being transferred to the drive motor reducer through the support rollers [4].

The gear motor housing is suspended in a balanced way. The reactive moment arising on the housing of the geared motor when the braked wheel is spinning is perceived by the force measuring system and transmitted to the data processing system [5].

Measuring complex check for diagnostics of 7500, 7700, 8600, 1000, 10000 series. BILANMATIC vehicle brake system and suspension is being performed in accordance with the document: “Measuring complex for diagnostics of 7500, 7700, 8600, 1000, 10000 series. BILANMATIC vehicle brake system and suspension of “Actia Muller Services” firm France. Calibration procedure” approved by SRC SI POCTECT- MOSCOW in May 2006 [6].

Procedure for research of brake system performance efficiency.
Conditions for conducting brake system testing [7]:
1. Testing was conducted in a laboratory environment, indoors, at the brake stand with chassis dynamometers;
2. Ambient air temperature 20°C ±10°C;
3. Electric power system voltage 220/380В with deviation from nominal values not exceeding +15% and -10%, electrical wiring insulation had no damages;
4. Stand rollers surface has no shears and cracks, is clean, having no oil spots and other defects influencing stand operational qualities;

Testing procedure: Prior to testing start minimal number of acceptable measurements have been determined for all the measurable parameters [8].

Experimental study algorithm is given at Figure 1.
**Experimental study objective**

To assess influence of brake system technical state operational changes to its operational efficiency depending on vehicle mileage

**Task**

To set up the regularities of the relationship between the wear of friction linings, the magnitude of the braking force on the control of the brake system when checking on the front, rear axles and separately on each wheel, with the vehicle mileage in order to derive an empirical relationship for their description.

**Material and technical resources**

- brake stand BILANMATIC MULLER 7700;
- double-column lift;
- measuring devices.

**Test item**

Vehicle of Toyota Camry (XV50) model

**Experiment conditions**

- technically sound brake system;
- brake systems have been dried out;
- tyre pressure is within the norm;
- tread depth at the center is not less than 1 cm;
- Ambient air temperature 20°C ±10°C;
- Electric power system voltage 220/380 V with deviation from nominal values not exceeding ±15% and -10%.

**Experiment method**

- GOST 51709-2004;
- workplace health and safety rules and regulations;
- technical regulations on safety of wheeled transport means.

**Measured parameters**

- friction lining thickness;
- braking force on the wheels of the front and rear axles;
- brake system response time.

**Methodological data evaluation**

- assessment of the measurements sufficiency at one point;
- finding the absolute error in determining the true value of the desired quantity.

**Figure 1 - Structural approach to the experimental research**

Measurements number estimate is performed using the chart (1):

\[ n \geq \frac{[t(P)]^2}{\varepsilon^2} \sigma^2, \]  

where \( t(P) \) is given in Table 2.

<table>
<thead>
<tr>
<th>( t=t(p) )</th>
<th>( P )</th>
<th>( t=t(P) )</th>
<th>( P )</th>
<th>( t=t(P) )</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.960</td>
<td>0.95</td>
<td>2.612</td>
<td>0.991</td>
<td>2.878</td>
<td>0.996</td>
</tr>
<tr>
<td>2.054</td>
<td>0.96</td>
<td>2.652</td>
<td>0.992</td>
<td>2.968</td>
<td>0.997</td>
</tr>
<tr>
<td>2.170</td>
<td>0.97</td>
<td>2.697</td>
<td>0.993</td>
<td>3.090</td>
<td>0.998</td>
</tr>
<tr>
<td>2.326</td>
<td>0.98</td>
<td>2.748</td>
<td>0.994</td>
<td>3.291</td>
<td>0.999</td>
</tr>
<tr>
<td>2.576</td>
<td>0.99</td>
<td>2.807</td>
<td>0.995</td>
<td>3.320</td>
<td>0.9991</td>
</tr>
</tbody>
</table>

Upon parameters equal observations, required fiducial accuracy shall be within interval \( 0.5 \sigma < |a - x| < \sigma \) with reliability 0.95 < \( P < 0.99 \) [7]. We presume \( a - x \leq 0.7 \sigma, P=0.96 \). Then number of measurements, defined using formula (2), will be as follows:

\[ n > \frac{2.054^2}{0.7^2} = 8.6 = 9. \]
1 is to be added to the reported value and we get \( n = 10 \).

**Measurements algorithm** [9]:
1. Prior to start brake testing the transport means under test is to be installed onto the lift in order to inspect and check: the condition of the brake mechanisms (calipers, brake hoses, cylinders); tire pressure; brake fluid level, as well as the absence of air locks in the circuit.
2. Thickness of the friction linings is measured and the actual sample of the vehicle is recorded at the time of its inspection. Then transport mean is to be moved to the diagnostic line BILANMATIC MULLER 7700.
3. Measuring devices are to be connected and the program started.
4. Data on the transport means under test is being introduced and a transition is made to the readiness for measurements.
5. Pedometer is being installed, which is a load cell measuring applied force on the brake control and connecting the measuring equipment.
6. Transport means under test is to be installed at the stand rollers observing the perpendicularity of the longitudinal axis of the vehicle to the axis of the rollers. Speed shifter is to be set in the neutral position. Having waited for the automatic start of electrical engines, front axle wheels start rotation (Fig. 2).
7. Holding the steering wheel firmly without impact, gently pressing the brake pedal, the measuring instruments record the values of the braking forces from the right-hand side and left-hand side wheels, as well as the values of the effort on the brake control and the brake system response time [10].
8. Having turned on the first gear or the “Drive” mode (automatic transmission), the vehicle smoothly drives out with the front axle from the rotating rollers. Having approached the rollers with the rear axle (without driving over them), stop the vehicle to automatically transfer the program to the mode of starting measurement on the rear axle. Measurements are made similar to braking actions on the front axle [11].

![Figure 2 - Braking power measurements on front (a) and rear (b) axle](image)

Measurements are made in accordance with the brake control checking procedure as per GOST P 51709-2001 included into the Technical regulations on wheeled transport means safety, operating manual of BILANMATIC MULLER 7700 stand.

**Results and Discussion**

Obtained results for Toyota Camry (XV50) vehicle are given in Table 3.
**Table 3 - Toyota Camry (XV50) measurement results**

<table>
<thead>
<tr>
<th>Measured parameters</th>
<th>Parameters value upon mileage (thousand km):</th>
</tr>
</thead>
<tbody>
<tr>
<td>Friction lining thickness, mm</td>
<td>10  9  8.5  8  7.5  6.5</td>
</tr>
<tr>
<td>Brake system response time upon actual thickness of friction linings, s</td>
<td>0.54 0.56 0.67 0.65 0.74 0.73 0.78</td>
</tr>
<tr>
<td>Effort on the brake pedal when braking on the axle, N:</td>
<td></td>
</tr>
<tr>
<td>front</td>
<td>55  102  129  132  147  153  186</td>
</tr>
<tr>
<td>rear</td>
<td>135 204  219  242  257  263  298</td>
</tr>
<tr>
<td>Braking force on the front wheel, kN:</td>
<td>4.68 4.51 4.48 4.41 4.34 4.31 3.98</td>
</tr>
<tr>
<td>Left-hand side</td>
<td>4.81 4.67 4.61 4.59 4.42 4.43 3.95</td>
</tr>
<tr>
<td>Right-hand side</td>
<td></td>
</tr>
<tr>
<td>Braking force on the rear wheel, kN:</td>
<td>2.79 2.81 2.74 2.52 2.54 2.34 2.25</td>
</tr>
<tr>
<td>Left-hand side</td>
<td>2.78 2.69 2.67 2.58 2.59 2.36 2.29</td>
</tr>
<tr>
<td>Right-hand side</td>
<td></td>
</tr>
</tbody>
</table>

Thanks to introduction of the modern method, obtained results are possible to be indicated in graphs, in the form of oscillograms for more detailed research of the controlled parameters behavior [12]. Results of the conducted testing are presented in the form of developed expert-diagnostic map (Figure 3).

![Figure 3 - Results of the braking force measurements on front (a) and rear (b) axle](image)

Proposed map shows comparison of the actual parameters results with the standard indicators on the test run, registers organoleptic examination results.

In conclusion, recommended values of brake parameters are given for expert research
taking into account brake system condition assessment as of transport means inspection time.

Conclusions.
As a result of conducted experimental research irrefutable evidence has been obtained indicating that disc brake friction linings thickness of the vehicle considerably effects brake system response time and the force on to brake pedal in case of emergency braking.

Upon vehicle mileage from 0 to 30000 thousand km thickness of friction lining changes from 10 to 6.5 mm, i.e. wear makes about 35% that results in increase of brake system response time from 0.54 to 0.78 s, increase by 45%. This allows to presume that greater wear causes rapid, abrupt increase of brake system response time reducing driver`s efforts and capabilities to zero result during emergency braking.

Brake pedal force with the same thickness of friction lining changes for the front(leading) axle from 55 to 186 N(by 240%); rear axle from 130 to 298 N(by 120%), that actually reduces chance of efficient braking.

To ensure proper update of the quantitative assessment of the influence degree of various operational factors on the vehicle braking process, it is necessary to use mathematical-probabilistic methods.

Acknowledgements. During the execution of the experimental part of the manuscript, the staff of Mega Motors LLP was assisted. The authors express their gratitude to the management and employees of Mega Motors LLP.

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Yermek Baubekov, doctor of technical sciences, professor, Academy of logistics and transport, Almaty, Kazakhstan, baubekov3@mail.ru

Gabit Bakyt, PhD, professor, Academy of logistics and transport, Almaty, Kazakhstan, gaba_b@bk.ru