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INFLUENCE OF SELECTED PARAMETERS ON THE QUALITY OF TECHNICAL TESTS BRAKING SYSTEM

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Purpose: The aim of the study is to find out whether and to extent the change of selected parameters of the system, such as the type of tires, tire pressure and axle load, changes the result of the technical test of the analysed vehicle in the field of measuring braking forces.
Design/methodology/approach: Diagnostic tests, tire pressure measurements, axle load measurements, braking force measurements on a roller device were carried out.
Findings: The relationships between the pressure in the tires and the braking force measured on the wheel as well as between the braking force and the load acting on the vehicle axle have been demonstrated.
Research limitations/implications: Mathematical relationships between tire pressure and vehicle braking force can be derived in the future.
Practical implications: In the course of the tests, it was found that the technical tests made it possible to determine the braking forces only while maintaining the nominal $\pm 1\times 10^5$ Pa tire pressure. Changes to this parameter may influence the measurement results. Moreover, the influence of tire pressure on the change of the measured braking force values was found, which translates into the safety of the vehicle in road traffic.
Originality/value: approach to brake system.

Keywords: safty and quality of transport, braking system, tire pressure.

Category of the paper: Technical paper.

1. Introduction

The continuous development of transport, the growing number of vehicles moving on the roads means that the requirements for the construction and reliability of vehicles are increasing. More and more demands are placed on their quality and safety. One of the main requirements is an efficient braking system, i.e. one that ensures a gradual reduction of the driving speed until the vehicle comes to a halt and with a pressure of 50 daN on the foot brake pedal, it will allow to achieve 60% of braking efficiency (Journal of Laws of 2015, item 776). Additionally, in accordance with the Road Traffic Law, the difference in braking forces between the wheels of one axle cannot be more than 30% in relation to the wheel with greater braking force. Literature data indicate cause-effect relationships between the braking distance of vehicles and the condition of the road surface on which they maneuver (Borkowski, 1973; Graczyk, 2010), type of tires (winter, summer), condition of the tire tread (Krzyżewska, 2019; Varghese, 2013; Reiter, Wagner, 2010) as well as tire pressure (Pawar et al., 2020; Szczucka-Lasota et al., 2021). The authors of the studies (Kasprzak et al., 2006; Li et al., 2011) also indicate the influence of the mass of the transported goods and the pressure exerted on the axles of the vehicle, both on the condition of the tires and the braking distance of the vehicle. In the light of the published test results and the described cause-and-effect relationships, it should be considered whether the described above factors may have a negative impact on the result of the technical examination of the vehicle.

The aim of the study is therefore an attempt to answer whether and to what extent the change of selected parameters of the system, such as the type of tires, tire pressure and axle load, results in a change in the result of the technical test of the analyzed vehicle in the field of braking force measurement. Are the registered changes significant enough to change the overall result of the quality test and the final decision made on the admittance of the vehicle to traffic.

2. Materials and research methods

To achieve the aim of the work, diagnostic tests were used, which were carried out at an operating vehicle inspection station. A roller device for measuring braking forces was used in the research (Figure 1a-1d) and three randomly selected passenger cars: Volkswagen Lupo, Audi A4, Renault Espace (Figure 2a).

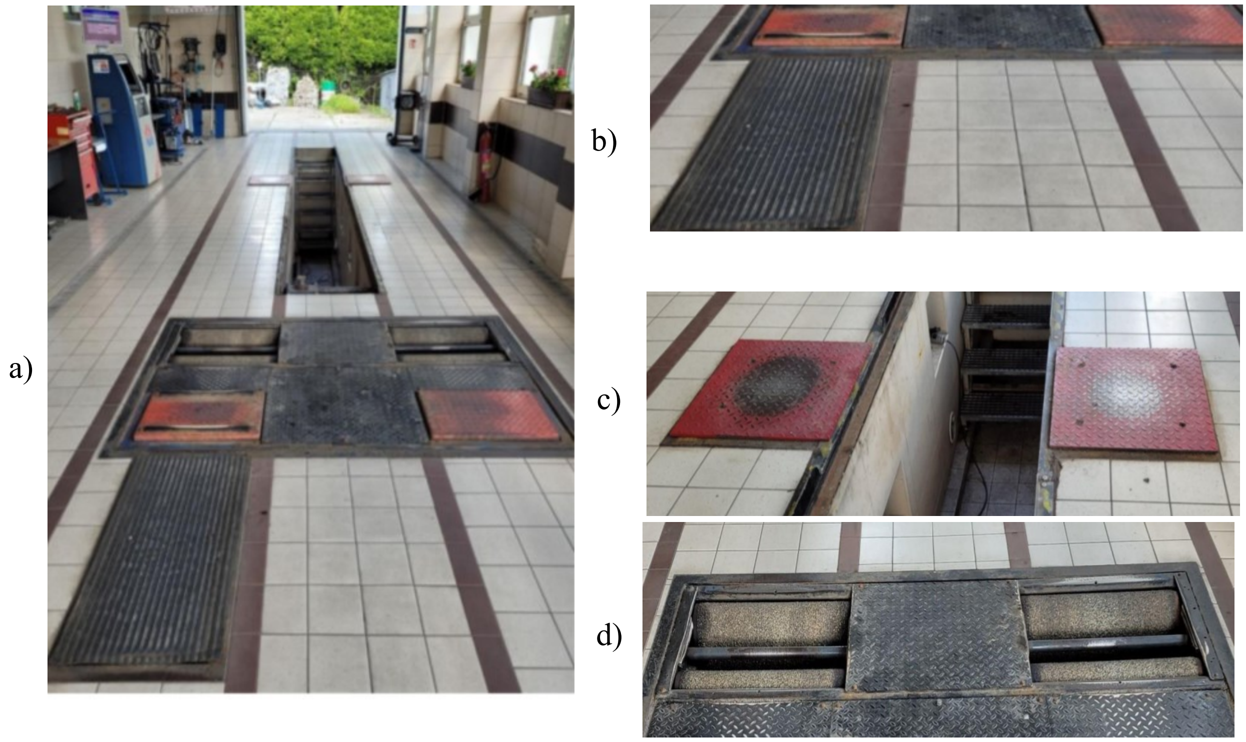

Figure 1. Diagnostic path a) general view b) roller device for measuring braking forces, b) plates for initial measurement of wheel alignment and shock absorber tester, c) sack and diagnostic channel.

It was found that the test with the use of various vehicles will provide higher reliability of the obtained results than the test of one type of vehicle. During the research, the MAHA diagnostic line was used, consisting of the following devices: the MINC1 toe-in tester, FWT1 shock absorber control device, IW2 roller brake control device, brake pedal pressure sensor, remote control of devices (Figure1-2).

At the time of the tests, all devices were operational, correctly set, in accordance with the principles of measuring the braking forces, and had valid tests, inspections and certifications necessary to conduct tests at a vehicle inspection station. Before starting the tests, the diagnostic path remote control was paired with a computer and a pad for measuring the pressure on the brake pedal. Before entering the diagnostic path, the pressure in the tires was adjusted (Figure 2b). The pressure was set in accordance with the recommendations of the vehicle manufacturer to the nominal values (table 1) or it was lowered from this value by $\pm 1\times10^5$ Pa, so that the difference between the nominal and the set pressure was the maximum allowed in the technical test of the passenger car, specified in (RMIiR of 18 December 2013).

Figure 2. Preparation for technical testing of braking forces measurement, a) test vehicles, b) adjustment and measurement of tire pressure, c) installation of a cover on the brake pedals of the tested vehicles.

Pressure regulation was carried out using a certified Wika pressure gauge. Each of the tested vehicles with nominal tire pressure was subjected to three measurements on summer tires and three measurements on winter tires on the dynamometer (Figure 3). Similarly, tests on the dynamometer were performed with the use of reduced pressure on the tires. Only the front axle of the vehicle was tested. Each time, after adjusting the pressure in the tires, the installation of a cover with a sensor measuring the force pressure on the brake pedal during braking was started (Figure 2c).

Table 1.
Nominal tire pressures for the front wheels of the tested vehicles

Vehilcle – brand	Nominal pressure read from the vehicle nameplate
Volkswagen Lupo	± 2×10^5 Pa
Audi A4	± 2.5×10^5 Pa
Renault Espace	± 2.5×10^5 Pa

The next step was to drive through the plate for measuring the initial toe-in of the wheels and the shock absorber tester. At the time of testing the braking system on the roller device, the measured axle load of the vehicle expressed in daN was displayed on the monitor (Figure 3a-3c). Then the vehicle drove the front axle onto the roller device. The rollers were started. The driver of the vehicle held a pilot in his hand. When pressing the brake pedal on the remote control, the value of the force applied to the pedal was displayed.

Volkswagen Lupo **Audi A4** **Renault Espace**

a)

b)

c)

Figure 3. The course of the technical test of measuring the braking forces, a) setting the pressure of 50N on the brake pedal, b) measurements on a roller device, c) example measurement results.

For the purpose of the tests, the same force is applied to the brake pedal for each vehicle. The adopted force for the conducted research is 50 N (Figure 3a). When 50 N of the force exerted on the brake pedal is reached, the results of the braking forces for the left and right wheels and the difference between them are displayed on the monitor (Figure 3c). The values mentioned are expressed in kN.

3. Results and analysis

The tests were carried out on a diagnostic stand and in accordance with the methodology described in the previous chapter. The first vehicle to be tested was the Volkswagen Lupo, the next one was the Audi A4, and the last was the Renault Espace. All the obtained results of measuring the braking forces were compiled in a tabulated form. The recorded braking force measurements for vehicles equipped with summer tires and the calculated differences between the measurement results for the front wheels are presented in Table 2-3.

Table 2.
Recorded measurements of braking forces for front wheels of vehicles fitted with summer tires

	Braking force – average of three measurements [N] for vehicles with summer tires			
Vehicle – brand	**Left wheel, tires with nominal pressure**	**Right wheel, tires with nominal pressure**	**Left wheel, tires with lowered pressure**	**Right wheel, tires with lowered pressure**
Volkswagen Lupo	1130	1260	1090	1110
	1150	1230	1100	1100
	1120	1240	1050	1020
Audi A4	2080	2370	1820	1990
	2110	2250	1850	1980
	2090	2230	1830	1990
Renault Espace	3120	3100	3100	3060
	3100	3080	3070	3060
	3140	3100	3100	3080

The analysis of the results presented in tables 2 and 3 makes it possible to state unequivocally that the tested vehicles met the technical requirements for the annual braking system test, because the differences in braking forces on one axle, between the right and left wheel, did not exceed 30%.

Table 3.
Differences between braking force measurements for front wheels with summer tires

Vehicle – brand (measured axle load)	**Braking force - average of three measurements [N] for vehicles with summer tires**				**Braking force difference between right and left wheel**	
	A	**B**	**C**	**D**		
	Left wheel, tires with nominal pressure	**Right wheel, tires with nominal pressure**	**Left wheel, tires with lowered pressure**	**Right wheel, tires with lowered pressure**	**│A-B│**	**│C-D│**
Volkswagen Lupo (6350 N)	1133	1243	1080	1076	110 N (8.85%)	4 N (0.38%)
Audi A4 (9080 N)	2093	2283	1830	1990	190 N (8.33%)	153 N (7.71%)
Renault Espace (12070 N)	3120	3093	3096	3060	27 N (0.87%)	36 N (1.17%)

The pressure in the tires influenced the obtained test results. For example, the difference between the measured values of the braking force in the case of an Audi A4 vehicle for the left front wheel with summer tires with nominal pressure and with lowered pressure was 263 N, and for the right wheel as much as 293 N. was lowered by a value of $\pm1\times10^5$ Pa. Similar tests were carried out for vehicles equipped with winter tires.

The recorded braking force measurements for and the calculated differences between the measurement results for the front wheels are presented in Table 4-5.

Table 4.
Recorded measurements of braking forces for front wheels of vehicles fitted with winter tires

	Braking force [kN] for vehicles with summer tires			
Vehicle – brand	**Left wheel, tires with nominal pressure**	**Right wheel, tires with nominal pressure**	**Left wheel, tires with lowered pressure**	**Right wheel, tires with lowered pressure**
Volkswagen Lupo	1140	1250	1100	1120
	1130	1240	1100	1110
	1110	1260	1040	1030
Audi A4	2070	2300	1850	1990
	2090	2200	1840	2000
	2120	2370	1850	1980
Renault Espace	3100	3080	3100	3060
	3120	3100	3070	3060
	3150	3080	3100	3090

Table 5.
Differences between braking force measurements for front wheels with winter tires

<table>
<tr><th rowspan="3">Vehicle – brand (measured axle load)</th><th colspan="4">Braking force - average of three measurements [N] for vehicles with summer tires</th><th colspan="2">The difference in the braking force between the right and left wheel expressed in N and (%)</th></tr>
<tr><th>A</th><th>B</th><th>C</th><th>D</th><th rowspan="2">│A-B│</th><th rowspan="2">│C-D│</th></tr>
<tr><td>Left wheel tires with nominal pressure</td><td>Right wheel, tires with nominal pressure</td><td>Left wheel, tires with lowered pressure</td><td>Right wheel, tires with lowered pressure</td></tr>
<tr><td>Volkswagen Lupo (6350 N)</td><td>1126</td><td>1250</td><td>1080</td><td>1086</td><td>124 N (9.92%)</td><td>6 N (0.56%)</td></tr>
<tr><td>Audi A4 (9080 N)</td><td>2093</td><td>2290</td><td>1846</td><td>1990</td><td>197 N (8.61%)</td><td>144 N (7.24%)</td></tr>
<tr><td>Renault Espace (12070 N)</td><td>3123</td><td>3086</td><td>3090</td><td>3070</td><td>37 N (1,19%)</td><td>20 N (0,65 %)</td></tr>
</table>

Based on the results of measuring the braking forces (tables 4 and 5) of vehicles with winter tires, it can be concluded that the tested vehicles met the technical requirements for the annual braking system test. As in the case of summer tires, also in this case the differences in braking forces on one axle between the right and left wheels did not exceed 30%. There were also no significant differences between the test results presented in Tables 3 and 5 for the same wheels.

This means that the result of the technical test is not significantly influenced by the type of tires (winter, summer). On the basis of the obtained test results, it can be concluded that the pressure in the tires affects the measurement results. The differences between the value of the braking force for the wheels with the nominal tire pressure and the value of the braking force for the wheels with the reduced pressure are recorded.

Nevertheless, a reduction in pressure by the value of $\pm 1\times 10^5$ Pa (the maximum permissible value by which the pressure in the tires may be lowered during technical tests of vehicles), indicates that this change does not affect the final test result. The measurement results are within the prescribed standard. It can be concluded that the correct pressure in the tires will affect the level of road safety of the vehicle, and its significant changes from the nominal value may cause an extended braking time of the vehicle.

The recorded braking force measurements presented in the graph (Figure 4) show that with the increased axle load, the recorded braking forces of the vehicle increase, regardless of whether the vehicle has nominal or lowered tire pressure.

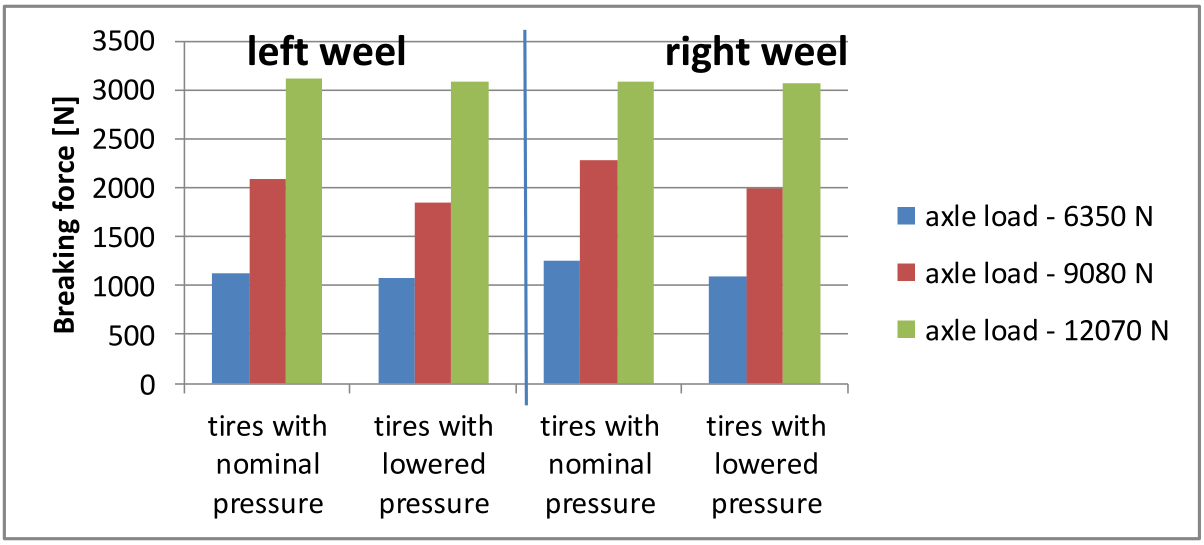

Figure 4. Braking force for front wheels with winter tires.

The axle load resulting from the vehicle structure does not affect the final result of the technical test of the vehicle, because the final evaluation takes into account the percentage values of the braking forces for the front and rear axles and the difference expressed as a percentage between the values obtained for the wheels of the same axle (cannot be more than 30%). The research results are consistent with the views presented by (Filipczyk, 2001). The observed relationship may be important for the vehicles carrying the load, especially in its improper distribution.

4. Summary

Summing up, it should be stated that there is a relationship between the pressure in the tires and the measured braking force of the vehicle. This relationship may affect the extension of the braking distance of the vehicle used on the road, when the correct nominal pressure in the tires is not maintained. In order to maintain appropriate safety measures, drivers should check and inflate their tires. The tire pressure permitted by law under the test conditions – technical inspection of the braking system - does not adversely affect the measurement results.

In the range of tire pressure changes by $\pm 1 \times 10^5$ from the nominal pressure, no significant differences in the results of the braking force measurement shall be recorded. The obtained results allow to conclude that the type of tires (summer, winter) does not significantly affect the recorded braking forces, the test results obtained for wheels with winter and summer tires are comparable. As the axle load increased, an increase in the braking force was recorded. However, the results were not translated into the final result of the technical braking test of the tested vehicles. All vehicles passed the tests positively.

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