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INFLUENCE OF TIRE PRESSURE ON THE VEHICLE BRAKING DISTANCE

JÓZEF STOKŁOSA[1], MAREK BARTNIK [2]

Abstract

The article presents the results of research on the influence of the pressure in car tires on the braking distance. Tires with lower than nominal pressure, higher than nominal pressure and for comparison with nominal pressure were analyzed. The tests were carried out on a bituminous surface typical for most road surfaces in Poland. Six tests were carried out on a dry surface, a wet surface, and a surface covered with snow. The cars were equipped with sets of summer and winter tires.

Keywords: road safety; vehicle braking; braking distance; tire pressure; winter tires; summer tires

1. Introduction

The tires of the car are the only element that each road vehicle has in contact with the road. The tires carry all the loads resulting from the kinematic excitations of the vehicle, participate in all forces acting between the road and the vehicle, of which we distinguish – acceleration, braking and steering. In order to ensure an adequate level of safety, tires are expected to meet a number of often contradictory criteria in all road conditions: on dry and wet surfaces, in low and high ambient and road temperatures, on various types of road surface. The tire's ability to transmit responses between the vehicle and the road is unfortunately limited. It is determined by a number of factors, the values of which deteriorate not only with changes in the technical condition (wear) of the tires, but also due to improper use. It results from the fact that with the wear of tires, their ability to perform their functions properly decreases, and therefore driving safety is reduced. Establishing the relationship between the mileage and the technical condition of car tires is a significant problem of road safety. Along with the wear of the tires, the so-called drainage volume of the tread, which is directly related to its tread height [1, 5, 6] and [7, 11, 20] as in the works [17, 19] is reduced. Of particular importance is the effect of various parameters on the vehicle's braking distance. The paper [16] presents the results of tests of braking deceleration of vehicles on wet and dry surfaces without specifying the type of tires in a state close to the limit state, i.e. with a tread groove depth of 2 mm

[1] University of Economics and Innovation in Lublin, Projektowa 4, 20-209 Lublin, Poland, e-mail: jozef.stoklosa@wsei.lublin.pl ORCID: orcid.org/0000-0003-1266-6945

[2] University of Economics and Innovation in Lublin, Projektowa 4, 20-209 Lublin, Poland, e-mail: marek.bartnik@wsi.lublin.pl

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(according to Polish regulations, the permissible depth of tread grooves in a given place may be 1.7 mm). The test results confirmed the hypothesis that a vehicle equipped with "old" tires (over 8 years of use) is characterized by a lower braking deceleration value, therefore the total braking distance is extended compared to tires with a tread depth of 3 mm. The study [16] drew attention to the degree of tread wear, and thus the deterioration of the water drainage conditions from the contact surface of the tire with the road. The author analyzed the tire wear process in the context of the formation of aquaplaning that impairs vehicle control. The works [2, 3, 13] and [8, 9] show the relationship between the pressure in the vehicle tires and fuel consumption as well as vehicle controllability. The works [10, 12, 14] and [15, 18, 21] presented the resistance of tires for vehicle against the rolling and sliding.

The aim of this study is to investigate the influence of pressure in car tires on the braking distance, to present the test results and to analyze them. The research on the influence of tire pressure on the braking distance was carried out with two practically identical cars with very similar curb weight (1430 kg and 1450 kg) and the same tire sizes 195/65 R15 (Table 1). Both vehicles were equipped with an efficient ABS system, whose task is to prevent the wheels from locking during braking, making the braking of the vehicle more effective. Due to the fact that the influence of tire pressure on the braking distance was investigated, all measurement tests were performed at a speed of 50 km/h. Speed measurements were made using the application installed on a mobile device.

Tab. 1. Basic parameters of vehicles participating in the experiment

	Vehicle with summer tires:	Vehicle with winter tires:
Vehicle model	Volkswagen Passat B5	Volkswagen Passat B5 FL
Year of production	1998	2000
Engine	1.9 TDI 90 KM	1.9 TDI 110 KM
Curb weight	1425 kg	1450 kg
Tire manufacturer	GoodYear Dura	Dębica Frigo 2
Tire size	195/65 R15	195/65 R15
Tire production year	2016	2020
Tread type	asymmetric	symmetrical directional
Tread height	6 mm	7 mm

The following values were adopted in the tests: nominal pressure 0.2 MPa, overpressure 0.3 MPa, and underpressure 0.10 MPa.

Tests on the influence of pressure on the braking distance for both summer and winter tires on dry and wet asphalt were carried out on a road with low asphalt roughness. When testing the braking distance for snow-covered asphalt, the road was completely covered with snow, so the tires did not come into contact with the asphalt surface during braking. The ambient temperature during the snow tests was –1° Celsius, for measurements on dry asphalt 3° Celsius and 2° Celsius for measurements on wet asphalt.

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2. Description of the course of measurements

Attempts to measure the influence of pressure on the braking distance consisted of accelerating the vehicle to a constant speed of 50 km/h and then sudden braking until the vehicle stopped completely. After the vehicle stopped, the distances from the braking point to the stopping point were measured using a 60 m long measuring tape. For each pressure value, 6 measurements of the braking distance were made, and then the average value from all tests was determined. For each type of pavement, measurements were started from the pressure of 0.3 MPa, after the tests, the pressure was reduced by 0.05 MPa.

3. Measurement results

The Tables 2–7 and Figures 1–12 present the results of measurements of the pressure effect on the braking distance for lowered and increased pressure for summer and winter tires on wet, dry and snow-covered surfaces compared to the nominal pressure of 0.2 MPa for the tested tires and vehicles. The seventh attempt trial in each graph represents the arithmetic mean of the six measurements for each pressure. Table 2 presents the results of research on the effect of pressure on the braking distance for the GoodYear DuraGrip 195/65 R15 summer tire on dry asphalt. The speed for all tests was 50 km/h.

Tab. 2. Influence of pressure in summer tires on the braking distance on dry asphalt at 50 km/h

GoodYear DuraGrip 195/65 R15 summer tire						
Trial number	Speed [km/h]	Braking distance in [m]				
		0.10 MPa	0.15 MPa	0.20 MPa	0.25 MPa	0.30 MPa
1	50	11.50	11.80	10.85	11.30	11.15
2	50	10.80	12.05	11.80	10.90	11.18
3	50	11.45	11.50	10.20	11.70	12.30
4	50	12.10	11.10	11.30	10.90	11.10
5	50	11.20	12.40	11.95	11.70	12.20
6	50	11.70	11.70	11.50	11.00	11.50
Mean	**50**	**11.46**	**11.76**	**11.27**	**11.25**	**11.57**

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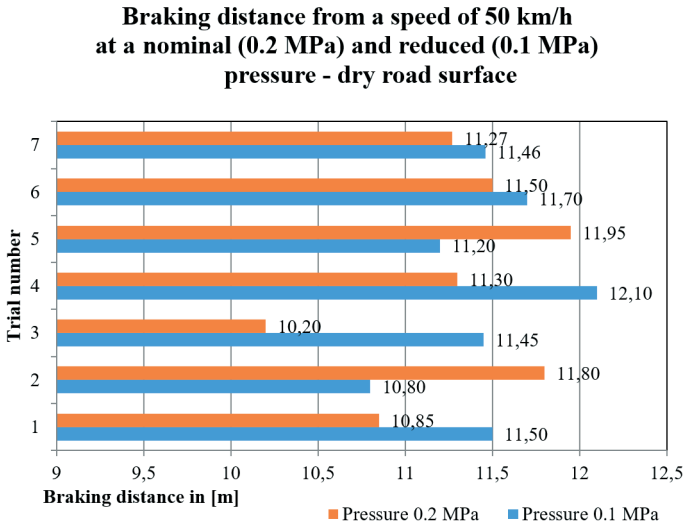

Fig. 1. Braking distance for the GoodYear DuraGrip 195/65 R15 summer tire on dry asphalt at a nominal (0.2 MPa) and reduced (0.1 MPa) pressure

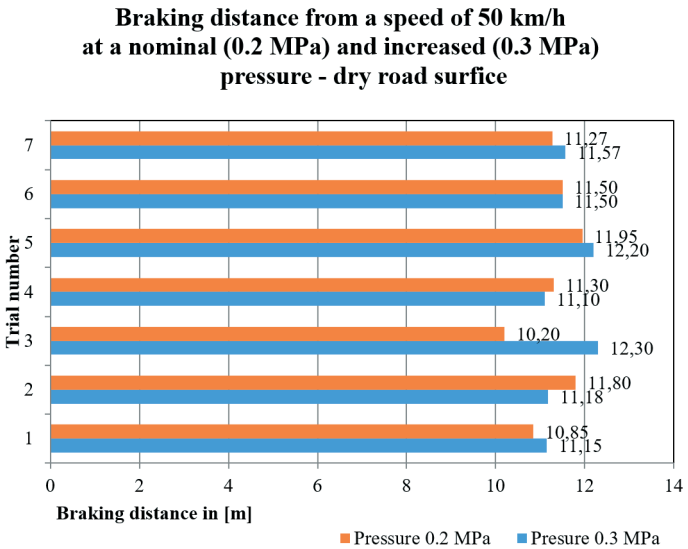

Fig. 2. Braking distance for the GoodYear DuraGrip 195/65 R15 summer tire on dry asphalt at a nominal (0.2 MPa) and increased (0.3 MPa) pressure

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Table 3 presents the results of research on the effect of pressure on the braking distance for the winter tire Dębica Frigo 2 195/65 R15 on dry asphalt. The speed for all tests was 50 km/h.

Tab. 3. Influence of pressure in winter tires on the braking distance on dry asphalt at 50 km/h

Winter tire Dębica Frigo 2 195/65 R15						
Trial number	Speed [km/h]	Braking distance in [m]				
		0.10 MPa	0.15 MPa	0.20 MPa	0.25 MPa	0.30 MPa
1	50	9.80	10.35	9.65	9.80	9.80
2	50	10.15	9.80	9.70	9.35	10.45
3	50	10.20	10.20	10.00	10.20	10.60
4	50	9.50	10.30	9.59	9.90	9.85
5	50	10.30	9.85	8.90	8.95	10.30
6	50	10.00	10.10	10.20	10.30	1010
Mean	**50**	**9.99**	**10.10**	**9.67**	**9.75**	**10.18**

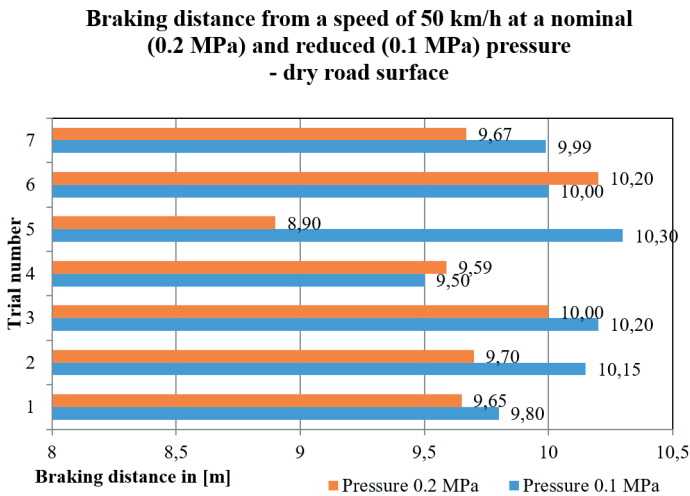

Fig. 3. Braking distance for the winter tire Dębica Frigo 2 195/65 R15 on dry asphalt at a nominal (0.2 MPa) and reduced (0.1 MPa) pressure

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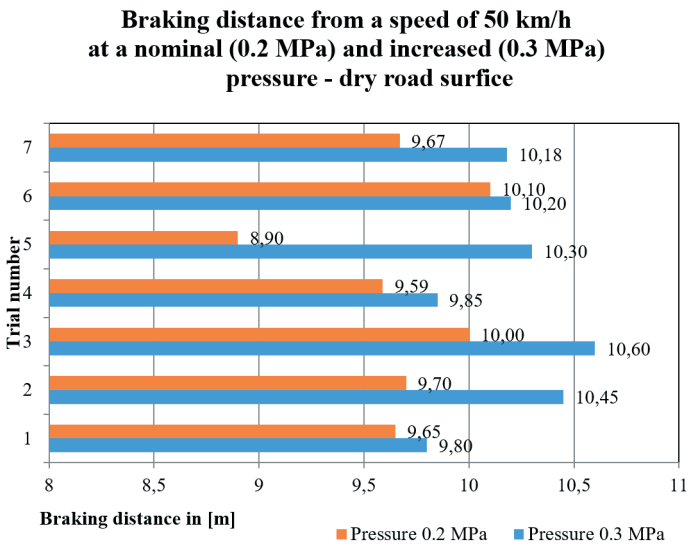

Fig. 4. Braking distance for the winter tire Dębica Frigo 2 195/65 R15 on dry asphalt at a nominal (0.2 MPa) and increased (0.3 MPa) pressure

Table 4 presents the results of research on the effect of pressure on the braking distance for the summer tire GoodYear DuraGrip 195/65 R15 on wet asphalt. The speed for all tests was 50 km/h.

Tab. 4. Influence of pressure in summer tires on the braking distance on wet asphalt at 50 km/h

GoodYear DuraGrip 195/65 R15 summer tire						
Trial number	Speed [km/h]	Braking distance in [m]				
		0.10 MPa	0.15 MPa	0.20 MPa	0.25 MPa	0.30 MPa
1	50	16.90	17.10	16.10	16.80	16.70
2	50	18.10	16.90	16.80	17.00	18.10
3	50	17.50	17.20	17.50	16.90	17.20
4	50	17.90	16.50	16.40	17.10	17.90
5	50	17.20	16.70	17.20	17.50	16.40
6	50	16,60	16.90	16.90	17.20	17.50
Mean	**50**	**17.37**	**1.88**	**16.82**	**17.08**	**17.30**

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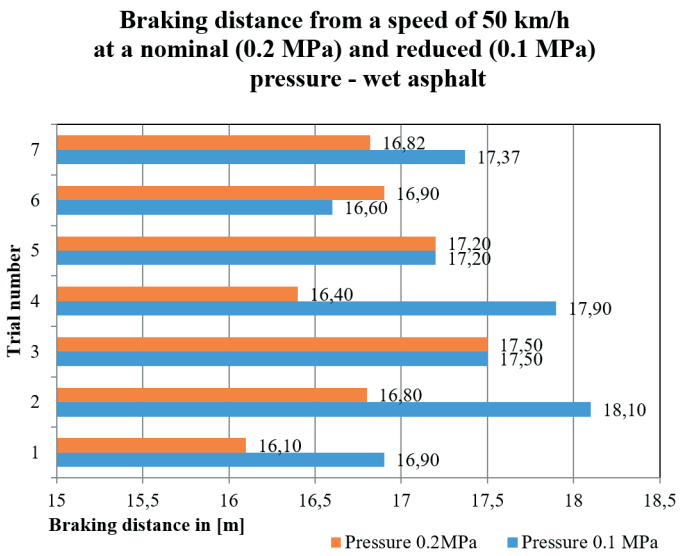

Fig. 5. Braking distance for the GoodYear DuraGrip 195/65 R15 summer tire on wet asphalt at a nominal (0.2 MPa) and reduced (0.1 MPa) pressure

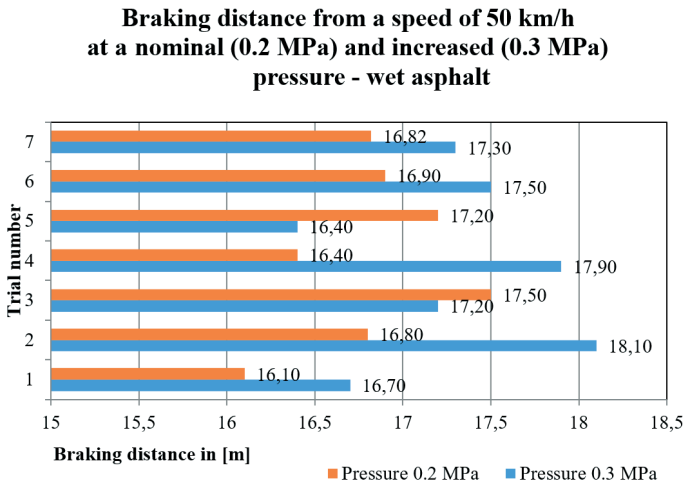

Fig. 6. Braking distance for the GoodYear DuraGrip 195/65 R15 summer tire on wet asphalt at a nominal (0.2 MPa) and increased (0.3 MPa) pressure

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Table 5 presents the results of research on the effect of pressure on the braking distance for the Winter tire Dębica Frigo 2 195/65 R15 on wet asphalt. The speed for all tests was 50 km/h.

Tab. 5. Influence of pressure in winter tires on the braking distance on wet asphalt at 50 km/h

Winter tire Dębica Frigo 2 195/65 R15						
Trial number	Speed [km/h]	Braking distance in [m]				
		0.10 MPa	0.15 MPa	0.20 MPa	0.25 MPa	0.30 MPa
1	50	15.90	15.20	15.30	15.70	16.20
2	50	16.20	14.90	15.10	16.20	15.90
3	50	15.80	15.50	14.70	14.90	15.30
4	50	14.60	14.70	15.90	15.20	15.70
5	50	16.40	14.50	14.60	14.70	1.,90
6	50	16.30	16.30	14.50	15.30	16.10
Mean	**50**	**15.87**	**15.18**	**15.02**	**15.33**	**15.68**

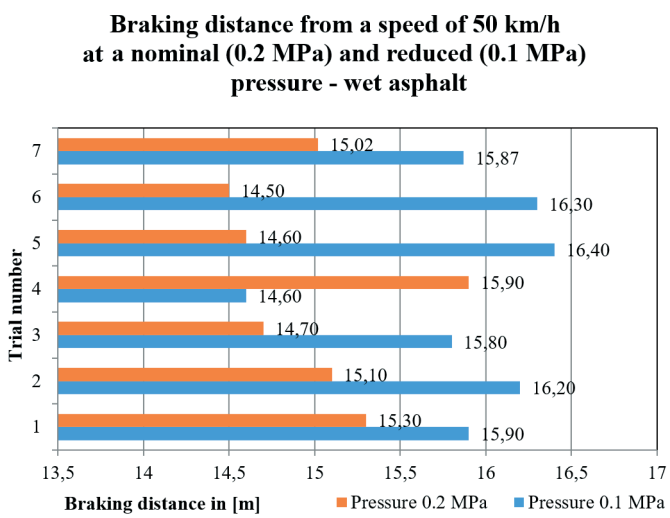

Fig. 7. Braking distance for Winter tire Dębica Frigo 2 195/65 R15 on wet asphalt at a nominal (0.2 MPa) and reduced (0.1 MPa) pressure

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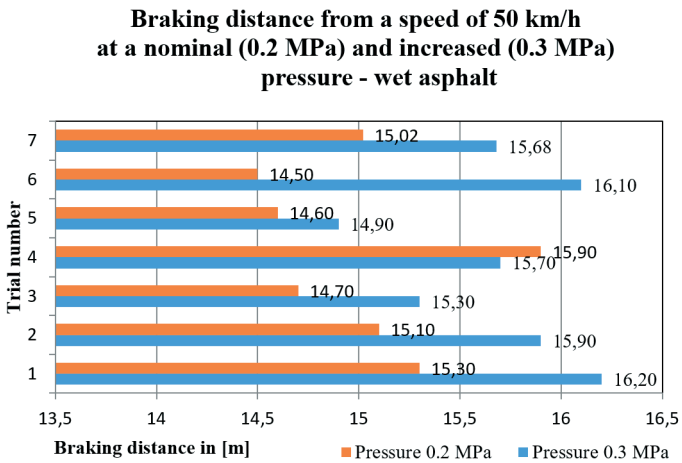

Fig. 8. Braking distance for Winter tire Dębica Frigo 2 195/65 R15 on wet asphalt at a nominal (0.2 MPa) and increased (0.3 MPa) pressure

Table 6 presents the results of research on the effect of pressure on the braking distance for the summer tire GoodYear DuraGrip 195/65 R15 on snow-covered asphalt surface. The speed for all tests was 50 km/h.

Tab. 6. Influence of pressure in summer tires on the braking distance on snow-covered asphalt surface at 50 km/h

GoodYear DuraGrip 195/65 R15 summer tire						
Trial number	Speed [km/h]	Braking distance in [m]				
		0.10 MPa	0.15 MPa	0.20 MPa	0.25 MPa	0.30 MPa
1	50	62.30	59.80	56.20	60.10	62.30
2	50	58.10	55.10	58.10	59.90	66.30
3	50	59.90	63.20	60.10	63.20	60.20
4	50	62.90	62.10	5..20	64.20	59.80
5	50	59.50	63.20	60.60	62.30	63.10
6	50	62.20	50.20	59.10	59.20	62.20
Mean	**50**	**60.40**	**59.70**	**58.05**	**61.80**	**62.32**

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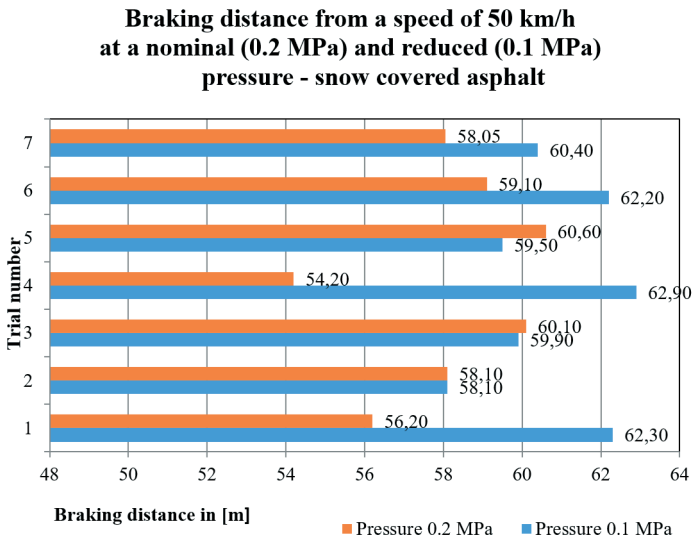

Fig. 9. Braking distance for the GoodYear DuraGrip 195/65 R15 summer tire on snow covered asphalt at a nominal (0.2 MPa) and reduced (0.1 MPa) pressure

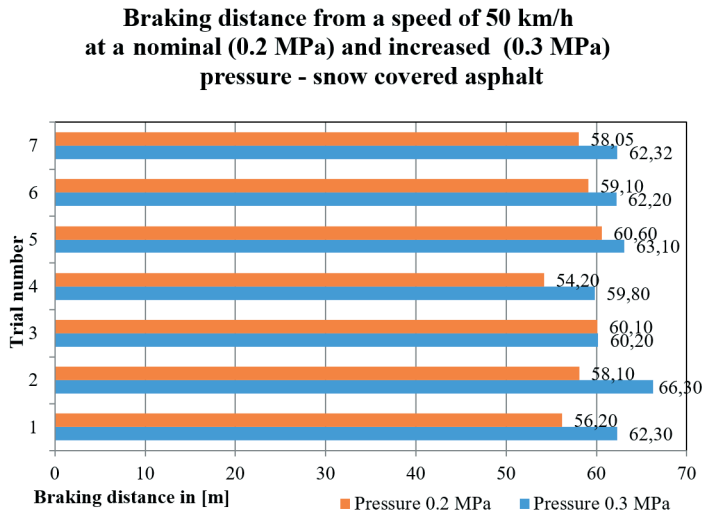

Fig. 10. Braking distance for the GoodYear DuraGrip 195/65 R15 summer tire on snow covered asphalt at a nominal (0.2 MPa) and increased (0.3 MPa) pressure

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Table 7 presents the results of research on the effect of pressure on the braking distance for the Winter tire Dębica Frigo 2 195/65 R15 on snow-covered asphalt surface. The speed for all tests was 50 km/h.

Tab. 7. Influence of pressure in winter tires on the braking distance on snow-covered asphalt surface at 50 km/h

Winter tire Dębica Frigo 2 195/65 R15						
Trial number	Speed [km/h]	Braking distance in [m]				
		0.10 MPa	0.15 MPa	0.20 MPa	0.25 MPa	0.30 MPa
1	50	25.10	23.50	22.80	25.30	25.90
2	50	24.80	24.20	24.80	26.50	26.20
3	50	26.10	22.90	26.50	26.70	28.10
4	50	24.20	26.20	23.50	23.20	26.00
5	50	25.60	24.80	25.00	26.10	25.10
6	50	24.80	25.30	22.50	27.20	25.20
Mean	**50**	**25.10**	**24.48**	**24.45**	**25.83**	**26.08**

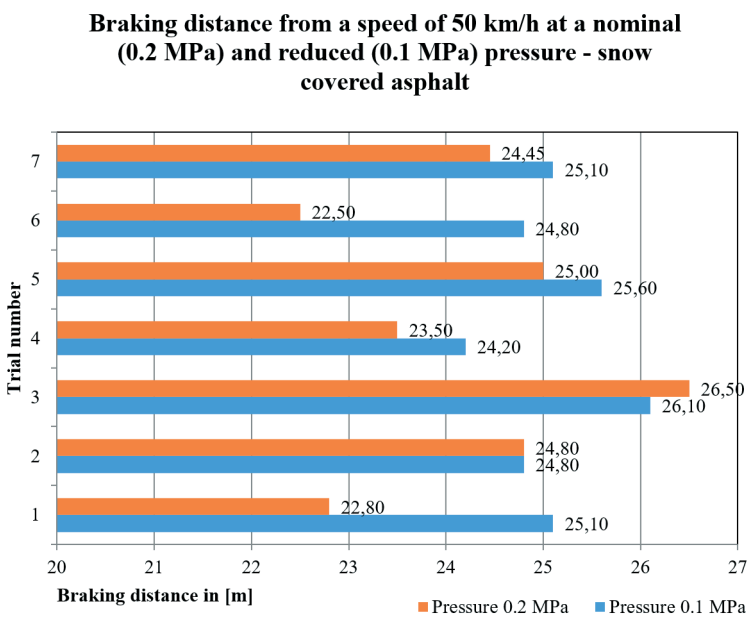

Fig. 11. Braking distance for Winter tire Dębica Frigo 2 195/65 R15 on snow covered asphalt at a nominal (0.2 MPa) reduced (0.1 MPa) pressure

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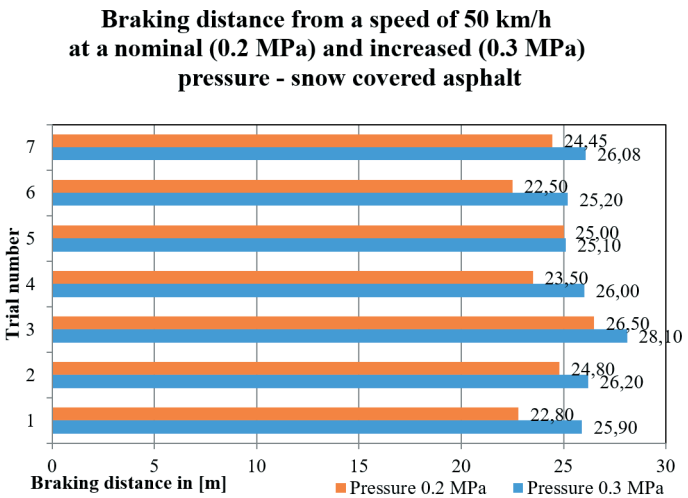

Fig. 12. Braking distance for Winter tire Dębica Frigo 2 195/65 R15 on snow covered asphalt at a nominal (0.2 MPa) and increased (0.3 MPa) pressure

4. Conclusions from the presented research results

From the above tables and graphs showing the braking distance, taking into account the arithmetic mean of the tests, the following conclusions can be presented:

a) dry bituminous surface (dry asphalt):
- reduced pressure in summer tires compared to the nominal pressure increased the braking distance by 0.19 m at 0.1 MPa and by 0.49 m at 0.15 MPa, and at increased pressure to 0.25 MPa, the braking distance was shortened by 0.02 m, while at the pressure of 0.3 MPa, the braking distance increased by 0.3 m
- for winter tires, the braking distance is 9.67 m, with an increase in pressure to 0.25 MPa, it increased to 9.75 m, and with a pressure of 0.3 MPa, it increased to 10.18 m. At a pressure of 0.15 MPa, the braking distance is 10.1 m. and at a pressure of 0. 1MPa, the braking distance is 9.99 m

b) wet bituminous surface (wet asphalt):
- the braking distance at the nominal tire pressure of a vehicle equipped with summer tires was 16.82 m, both for increased and lowered tire pressure, the braking distance was longer
- in the case of winter tires, the braking distance at nominal pressure was on average 15.02 m

c) bituminous surface covered with snow
- the braking distance of a vehicle equipped with summer tires at a pressure of 0.2 MPa

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of a vehicle equipped with summer tires was 58.05 m on average, and 24.45 m for winter tires
- lower pressure in both winter and summer tires allowed for a shorter braking distance compared to the braking distance of vehicles with tires with higher pressure

The conducted experiments showed unequivocally that for the safe use of vehicles, it is absolutely necessary to observe the principle that the pressure in the tires should be nominal. Low as well as high pressure in relation to the nominal pressure recommended by tire manufacturers increases the braking distance in practically all road conditions. It is worth noting here that, according to the research conducted by Michelin [4], in as many as 40% of the tested vehicles the pressure in the wheels was much too low or much too high.

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