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COMPARISON OF SUMMER AND WINTER TYRES ON A DRY AND SNOWY SURFACE

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The paper describes the comparison of braking properties of summer and winter tyres on a vehicle Škoda Octavia II, 2.0 TDI (103 kW), with summer tyres Michelin Pilot Primacy 225/45 R17 91W and winter tyres Dunlop SP Winter Sport 3D 195/65 R15 91T. Testing was done in summer on a dry asphalt road and in winter on a snowy asphalt road with compacted snow without gritting. A device for the measuring of deceleration was XL Meter Pro Alpha.

Keywords: braking, vehicle, deceleration, grip, tyre

Tyres are an important part of vehicles. They transfer traction, braking and lateral forces. Further, they transfer the weight of a vehicle to the ground and absorb shocks from road bumps. There is also required a low rolling resistance in order to reduce fuel consumption, and rolling with a low noise and low transfer of vibrations into the cabin.

The operation of vehicles with modern tyres on roads and motorways represents a new standard of drive comfort and transport safety. The implementation and use of winter tyres for passenger cars, light commercial vehicles and buses is now a very frequent question. The use of such tyres is confronted with their higher costs on one hand, and with anticipated improvements of adhesion properties, especially in difficult winter conditions under low temperatures, in the presence of a snow cover and also on frozen roads, on the other hand.

The objective of this paper is to give further information on the behaviour of summer and winter tyres in defined conditions in terms of transferring the braking forces during braking in a limited condition of 100 % slide on a dry road, and to follow the results of Janoško et al. (2007–2010), Abrahám et al. (2009, 2012), Jamrichová et al. (2003, 2012), and Sloboda et al. (2008).

Material and methods

The behaviour of selected summer and winter tyres was assessed on a dry asphalt road under temperatures recommended by manufacturers for replacing the summer and winter tyres.

Initial speeds were selected from the interval of 40, 60 and 90 km.h⁻¹, considering the wear of tyres and the length of a test road.

For the purpose of these experiments, summer and winter tyres were mounted on a vehicle with an ABS braking system. In addition to monitoring the reached deceleration values on individual types of tyres, also the age of tyres was taken into account.

Experimental measurements were performed with summer and winter tyres, on a dry asphalt-concrete road, next to Janíkovce village, under an air temperature of 13.0–14.5 °C. Comparative measurements were also done

in winter, on winter tyres with speeds 40, 60, and 90 km.h⁻¹, and subsequently on summer tyres with speeds 40, 50, and 70 km.h⁻¹. The measurement was performed on a side road covered with snow, with a smooth, compacted snow of 1–2 cm thickness without gritting, under air temperature $t = -1.5$ °C. On the base of those measurements, we have assessed the suitability of using the tested types of tyres in the summer and winter season.

External conditions during measurements

Air temperature: 13.0–14.5 °C (summer measurements)
-1.5 °C (winter measurements)

Wind: light north-east

Place of measurement: communication at Janíkovce village – Nitra, Veľký Cetín

Surface type: bitumen road, dry

Vehicle

Škoda Octavia II, 2.0 TDI, technical parameters (Table 1)

Tyres: Dunlop SP Winter Sport 3D 195/65 R15 91T (winter tyre)

Michelin Pilot Primacy 225/45 R17 91W (summer tyre)

Measuring device

Gravimetric XL meter (accelerating and decelerating), with software, the precision of measurement: $\delta = \pm 5$ %

Table 1 Technical parameters of Škoda Octavia II, 2.0 TDI

Vehicle make	Škoda Octavia II
Engine displacement	1,968 cm ³
Engine maximum power / RPM	103 kW / 4,000 min ⁻¹
Drive axle	Front
Gearbox	Mechanical 6-speed
Type of fuel	Diesel
Standby weight	1,335 kg
Brakes front / rear	Disc brakes / disc brakes
Year of manufacture	2007

Figure 1 Summer tyres Michelin Pilot Primacy 225/45 R17 91 W

Table 2 Technical parameters of the tested summer tyres

Type of tyres	Michelin Pilot Primacy 225/45 R17 91W
Year of manufacture (week/year)	16/2007, travelled 5,000 km
Pressure in the tyre FL	210 kPa
Pressure in the tyre FR	210 kPa
Pressure in the tyre RL	220 kPa
Pressure in the tyre RR	220 kPa
Depth of tread pattern FL	7.5–7.8 mm
Depth of tread pattern FR	7.5–7.8 mm
Depth of tread pattern RL	7.5–7.8 mm
Depth of tread pattern RR	7.5–7.8 mm

Figure 2 Winter tyres Dunlop SP Winter Sport 3D 195/65 R15 91T

Table 3 Technical parameters of the tested winter tyres

Type of tyres	Dunlop SP Winter Sport 3D 195/65 R15 91T
Year of manufacture (week/year)	17/2006, travelled 3,000 km
Pressure in the tyre FL	220 kPa
Pressure in the tyre FR	220 kPa
Pressure in the tyre BL	230 kPa
Pressure in the tyre BR	230 kPa
Depth of tread pattern FL	7.5–7.8 mm
Depth of tread pattern FR	7.5–7.8 mm
Depth of tread pattern BL	7.5–7.8 mm
Depth of tread pattern BR	7.5–7.8 mm

A mathematical model for the determination of kinematic parameters of the vehicle is based on the motion of a slowing body, where the following equations shall apply to time:

$$\int_{t_1}^{t_2} F \cdot dt = \int_{v_1}^{v_2} d(m \cdot v) \quad (1)$$

for distance:

$$\int_{s_1}^{s_2} F \cdot ds = \int_{v_1}^{v_2} d\left(\frac{1}{2} m \cdot v^2\right) \quad (2)$$

respectively:

$$s = \int_0^t v \cdot dt = \int_0^t a \cdot t \cdot dt = \frac{a \cdot t^2}{2} = \frac{v^2}{2a} \quad (3)$$

where:

F – braking force on the wheels

m – mass of the vehicle

v – initial vehicle speed

s – braking distance

a – deceleration

t – time of braking

For a detailed understanding of changes in slowdown, it is necessary to know the instantaneous deceleration over time. Exact deceleration was obtained by the gravity decelerator, where the examined deceleration MFDD (mean fully developed deceleration) is defined as follows:

$$MFDD = \frac{v_b^2 - v_e^2}{2.92 \cdot (s_e - s_b)}, \text{ m.s}^{-2} \quad (4)$$

where:

v_0 – initial speed at the start of braking, km.h⁻¹

$v_b = k_1 v_0$, $k_1 = 0.8$, km.h⁻¹

$v_e = k_2 v_0$, $k_2 = 0.1$, km.h⁻¹

s_b – distance travelled by the vehicle between speeds v_0 and v_b , m

s_e – distance travelled by the vehicle between speeds v_0 and v_e , m

Results and discussion

The braking deceleration of tyres in different conditions was implemented in 12 separate runs for different speeds. Each experimental measuring of deceleration was recorded with a sampling frequency of 200 Hz, and waveforms of velocity and travel were subsequently determined. A record was prepared from each limited deceleration, and all the results were prepared in the form of a table (Tables 4–7).

Some courses, as illustrated in Figures 3 and 4, were selected from individual measurements.

Table 4 Results of measuring the summer tyres Michelin Pilot Primacy 225/45 R17 91W under temperature $t = 13.0\text{--}14.5\text{ }^{\circ}\text{C}$, one person, dry surface

Vehicle	Škoda Octavia II, 2.0 TDI – with ABS		
Type of tyres	Michelin Pilot Primacy 225/45 R17 91W		
Type of road	Dry, asphalt-concrete		
Prescribed initial speed	40 km.h ⁻¹	60 km.h ⁻¹	90 km.h ⁻¹
Real initial speed – v_0	41.54 km.h ⁻¹	60.50 km.h ⁻¹	91.03 km.h ⁻¹
Braking distance – s_0	8.09 m	16.02 m	38.44 m
Braking time – T_{br}	1.33 s	1.84 s	2.85 s
Value of deceleration – MFDD	8.95 m.s ⁻²	9.87 m.s ⁻²	9.74 m.s ⁻²

Table 5 Results of measuring the winter tyres Dunlop SP Winter Sport 3D 195/65 R15 91T under temperature $t = 13.0\text{--}14.5\text{ }^{\circ}\text{C}$, one person, dry surface

Vehicle	Škoda Octavia II, 2.0 TDI – with ABS		
Type of tyres	Dunlop SP Winter Sport 3D 195/65 R15 91T		
Type of road	Dry, asphalt-concrete		
Prescribed initial speed	40 km.h ⁻¹	60 km.h ⁻¹	90 km.h ⁻¹
Real initial speed – v_0	42.66 km.h ⁻¹	63.40 km.h ⁻¹	90.98 km.h ⁻¹
Braking distance – s_0	9.50 m	21.5 m	44.35 m
Braking time – T_{br}	1.56 s	2.39 s	3.38 s
Value of deceleration – MFDD	7.89 m.s ⁻²	7.10 m.s ⁻²	7.72 m.s ⁻²

Table 6 Results of measuring the summer tyres Michelin Pilot Primacy 225/45 R17 91W under temperature $t = -1.5\text{ }^{\circ}\text{C}$, one person, snowy surface

Vehicle	Škoda Octavia II, 2.0 TDI – with ABS		
Type of tyres	Michelin Pilot Primacy 225/45 R17 91W		
Type of road	road covered with a compacted snow of 1–2 cm, without gritting		
Prescribed initial speed	40 km.h ⁻¹	50 km.h ⁻¹	70 km.h ⁻¹
Real initial speed – v_0	33.65 km.h ⁻¹	50.47 km.h ⁻¹	64.12 km.h ⁻¹
Braking distance – s_0	35.94 m	75.52 m	125.94 m
Braking time – T_{br}	7.64 s	11.20 s	14.40 s
Value of deceleration – MFDD	1.27 m.s ⁻²	1.31 m.s ⁻²	1.26 m.s ⁻²

Table 7 Results of measuring the winter tyres Dunlop SP Winter Sport 3D 195/65 R15 91T under temperature $t = -1.5\text{ }^{\circ}\text{C}$, one person, snowy surface

Vehicle	Škoda Octavia II, 2.0 TDI – with ABS		
Type of tyres	Dunlop SP Winter Sport 3D 195/65 R15 91T		
Type of road	road covered with a compacted snow of 1–2 cm, without gritting		
Prescribed initial speed	40 km.h ⁻¹	60 km.h ⁻¹	90 km.h ⁻¹
Real initial speed – v_0	38.01 km.h ⁻¹	62.80 km.h ⁻¹	87.79 km.h ⁻¹
Braking distance – s_0	19.91 m	44.50 m	91.44 m
Braking time – T_{br}	3.83 s	5.51 s	7.90 s
Value of deceleration – MFDD	3.08 m.s ⁻²	3.46 m.s ⁻²	3.36 m.s ⁻²

Figure 3 Record of limit deceleration of Škoda Octavia II, 2.0 TDI, Michelin Pilot Primacy 225/45 R17 91W, year of manufacture 2007, tyre tread depth 7.5–7.8 mm, speed 41.54 km.h⁻¹, asphalt-concrete road, dry surface, $t = 14.5\text{ }^{\circ}\text{C}$, one person

Figure 4 Record of limit deceleration of Škoda Octavia II, 2.0 TDI, Dunlop SP Winter Sport 3D 195/65 R15 91T, year of manufacture 2006, tyre tread depth 7.5–7.8 mm, speed 42.66 km.h⁻¹, asphalt-concrete, dry surface, $t = 13.0\text{ }^{\circ}\text{C}$, one person

Conclusion

The measured and aggregated results lead to the following conclusions:

- During the test of Škoda Octavia II with ABS in summer ($t = 13.0 - 14.5\text{ }^{\circ}\text{C}$), there was found a worse braking deceleration of winter tyres Dunlop SP Winter Sport 3D 195/65 R15 91T (year of manufacture 2006) as compared to summer tyres Michelin Pilot Primacy 225/45 R17 91W (year of manufacture 2007) on a dry road. It was the case of tyres after running-in, with about 3,000–5,000 km run. The measured results show that the summer tyres Michelin with a speed of $40-90\text{ km}\cdot\text{h}^{-1}$ reached the mean deceleration in the interval $a = 8.95-9.87\text{ m}\cdot\text{s}^{-2}$, and the winter tyres Dunlop in the interval $a = 7.1-7.89\text{ m}\cdot\text{s}^{-2}$, representing a reduction of deceleration amounting to about 20 – 21 %. However, at such a difference, winter tyres had a comparable deceleration to less powerful summer tyres. Excellent results of the summer tyres Michelin in combination with ABS reached deceleration $a = 0.9-1.0\text{ g}$ (g – gravimetric acceleration), which is actually a noteworthy value.
- When testing Škoda Octavia II with ABS in winter ($t = -1.5\text{ }^{\circ}\text{C}$), there was observed a worse braking deceleration of the summer tyres Michelin Pilot Primacy 225/45 R17 91W as compared to the winter tyres Dunlop SP Winter Sport 3D 195/65 R15 91T on a snowy road with a snow height of 1–2 cm. Based on the measured and aggregated experiments, it is possible to state that with the tested types of winter tyres we have reached better deceleration results at $a = 3.08-3.46\text{ m}\cdot\text{s}^{-2}$. The Michelin summer tyres reached deceleration at $a = 1.26-1.31\text{ m}\cdot\text{s}^{-2}$, which represents a decrease of deceleration by ca. 59–62 %. Such a significant reduction in deceleration will result in more than twice the braking distance. In addition to a worse compound in winter conditions, an unfavourable outcome of summer tyres is a result of a greater width of summer tyres, too.
- It follows from the above-mentioned facts that a suitable tread pattern as well as the composition of the compound itself has a significant effect on vehicle behaviour in limit situations, and the alternating of summer and winter tyres in different seasons has its own significance. Especially good winter tyres in winter represent a large increase in braking deceleration. These considerations are valid for age-comparable tyres.

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