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INVESTIGATION OF ADHESION CHARACTERISTICS OF DIFFERENT TYRE TYPES IN DIFFERENT WEATHER CONDITIONS

Janusz Pokorski, Andrzej Reński, Hubert Sar

Warsaw University of Technology, Institute of Vehicles, Section of Automobiles
Narbutta Street 84, 02-524 Warszawa, Poland
tel./fax: +48 22 8490303, +48 22 8490302
e-mail: januszpokorski@simr.pw.edu.pl, arenski@simr.pw.edu.pl, hubsar@wp.pl

Abstract

Tyre-to-road adhesion has a great influence on transmitting forces between wheels and road surface and in the consequence on the safety of automobile motion. It plays significant role in vehicle motion modelling, especially for the needs of traffic accidents reconstruction and the development of active safety systems in automobiles. Simultaneously, the knowledge about tyre-to-road adhesion is limited, especially in case of the differences between anti-slip properties of summer and winter tyres. In the paper, method of the measurement of tyre-to-road adhesion coefficient is presented. The measurement system SRT-4 consists of special dynamometer trailer, towing vehicle and test-measuring equipment. It was designed for the needs of road engineering and further developed in the Institute of Vehicles of Warsaw University of Technology. It enables to obtain adhesion characteristics, i.e. graph of adhesion coefficient as a function of wheel slip ratio. In the article, examples of tyre-to-road adhesion characteristics and velocity characteristics of peak adhesion coefficient for different types of tyres (summer, winter) in different weather conditions are presented. Differences in characteristics courses caused by tyre type and weather conditions are discussed. For instance, in case of winter tyres it was noticed that their peak value of adhesion coefficient was reached for higher values of slip ratio than it was observed for summer tyres.

Keywords: *tyre-to-road adhesion, skid resistance tester, traffic safety, accident reconstruction*

1. Introduction

The aim of conducted research was to investigate the influence of ambient temperature on adhesion of automotive wheel to road surface. In particular, differences in adhesion between summer and winter tyres on clean asphalt surface in determined temperature conditions were investigated. The basis of this evaluation was the friction force developed between tyre and road surface during wheel braking. To measure this force SRT-4 measurement system presented in Fig. 1 was applied. The system consists of dynamometer trailer and towing vehicle. Relevant structural arrangement of the trailer and test-measuring system (drawn up for the needs of road engineering by the Institute of Vehicles of Warsaw University of Technology [5]) let steer the braking torque acting on trailer measurement wheel (see Fig. 2) and measure signals necessary to obtain the friction force between wheel and road surface. Under the term „adhesion" (adhesion coefficient marked with μ symbol) authors of the article understand the quotient of this friction force and wheel normal reaction. In typical applications: towing vehicle is moving at constant velocity, measurement wheel is braked until it is completely locked. It is possible to conduct examinations on wet (water is being poured up to the measurement wheel) or on dry road surface.

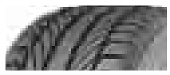
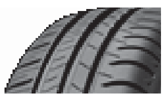
Figure 3 presents the signals measured during adhesion test. The measuring cycle lasts maximum 2 seconds. Braking torque applied to the brake disc (1-red line) causes the appearance of friction force between wheel and road surface (3-blue line) and decrease of wheel rotation velocity (2-green line). Having the measurement of friction force [3], wheel rotation velocity and vehicle velocity v at its disposal, in the time interval t_1 tyre-to-road *adhesion characteristic* μ(s) as a function of slip ratio s (see chapter 3, [1], [2]) is determined for steady-state velocity v. Obtaining average values of friction force in the time interval t_2 (with the wheel completely locked) for different wheel sliding velocities v *velocity characteristics* μ_o(v) are determined (see chapter 2).

Fig. 1. Measurement system SRT-4 – Mercedes-Benz Sprinter and dynamometer trailer

Fig. 2. Measurement wheel of dynamometer trailer

Information concerning tested tyres is placed in Tab. 1. The research was conducted in temperatures 13^{o}C, 2^{o}C and -15^{o}C on clean asphalt road surfaces (without ice and snow) for summer and winter tyres of two European tyre producers.

Tab. 1. Tested tyres: size - 185/65 R14, inflation pressure – 0.22 MPa

Tyre type	Tread geometry	
summer tyre L_1 – producer 1	directional	
winter tyre Z_1 – producer 1	directional	
summer tyre L_2 – producer 2	asymmetric	
winter tyre Z_2 – producer 2	directional	

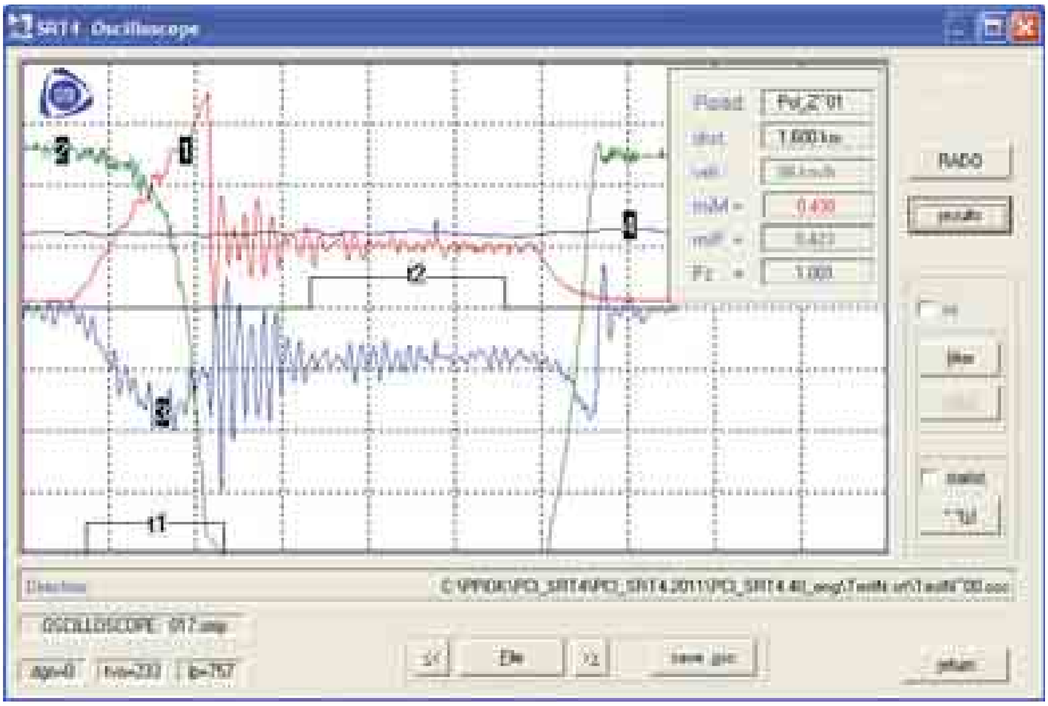


Fig. 3. Measurement signals of dynamometer trailer: 1-wheel velocity, 2-braking torque, 3-wheel friction force, 4-wheel normal load

For positive temperatures the investigations were carried out on wet and on dry national road with new SMA type surface. For negative temperatures the examinations were conducted on the chilled, dry surface in the area of Warsaw, also on new road surface.

2. Velocity characteristics $\mu_o(v)$

Figure 4 presents the selected velocity characteristic $\mu_o(v)$ for wet road surface in wide range of sliding velocity v for one of four tested tyres.

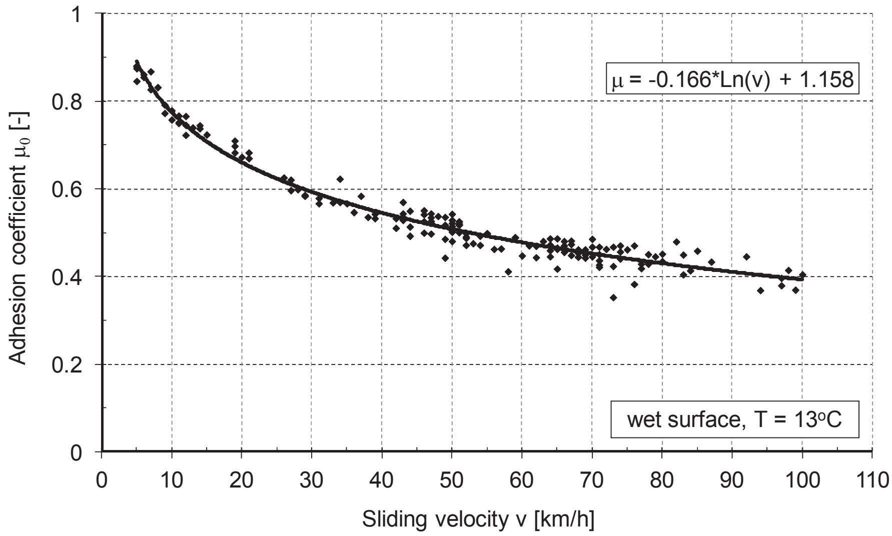


Fig. 4. Example of velocity characteristic $\mu_o(v)$

Figure 5 and 6 show velocity characteristics of adhesion for positive temperatures for summer and winter tyres on wet road surface. Irrespective of the type of the tyre (summer of winter) the influence of temperature on tyre-to-road adhesion is slight (Fig. 5) in the whole range of investigated velocities (30, 60, 90 km/h). It is characteristic that even for the temperatures close to the zero (Fig. 6) summer tyres develop higher friction force than winter tyres. The above observations concern tyres of both producers.

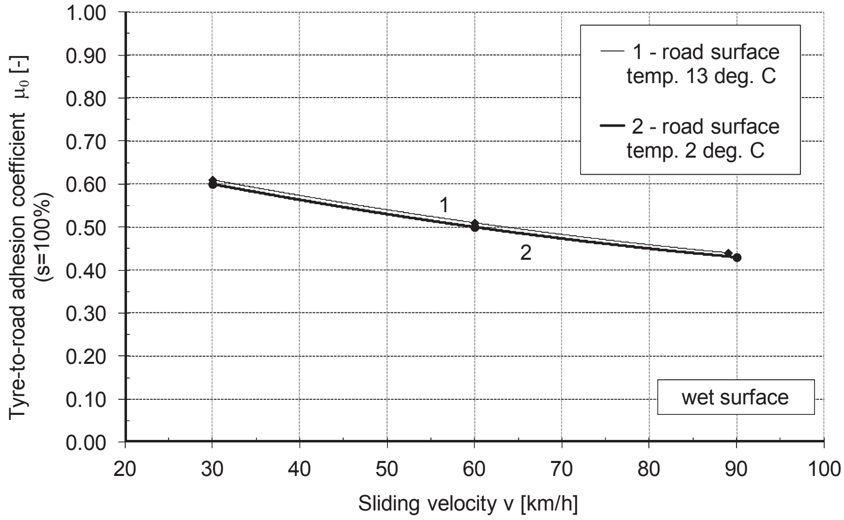


Fig.5. Velocity characteristics $\mu_o(v)$ for different ambient temperatures

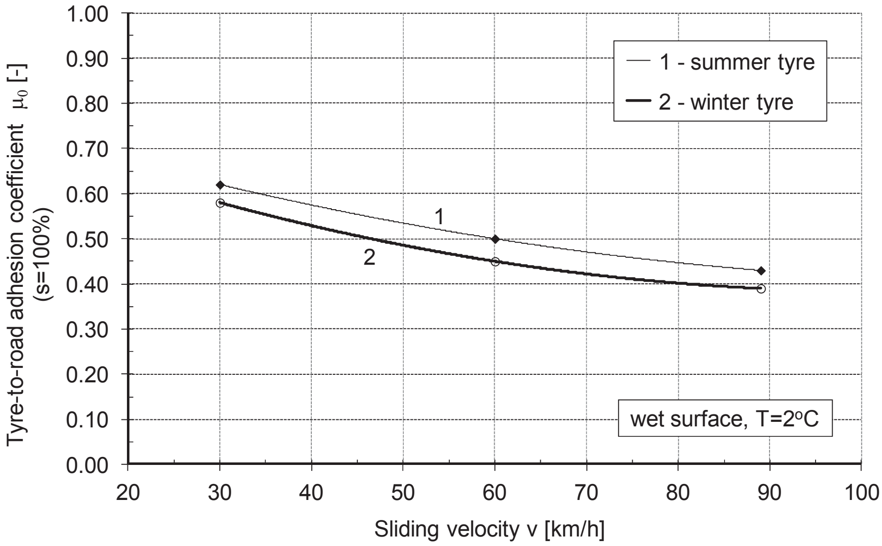


Fig.6. Comparison of summer and winter tyres

3. Adhesion characteristics μ(s)

Figures 7-10 present adhesion characteristics in the whole range of investigated ambient temperature (positive and negative).

It is characteristic that winter tyres are getting the peak adhesion coefficient for considerably higher values of slip ratio than summer tyres. Peculiarly it is clearly noticeable in Fig. 7 and 8. For positive temperatures (in the range between 1^{o}C to 13^{o}C) the peak adhesion coefficient values are higher for summer tyres. For the majority of obtained adhesion characteristics adhesion coefficient for summer tyre is higher than for winter tyre in the entire range of slip ratio. (Fig. 8).

Definitely for low temperatures (-15^{o}C) the adhesion characteristics of winter tyres are demonstrating about 25-30% higher values of adhesion coefficient practically in the whole range of slip ratio.

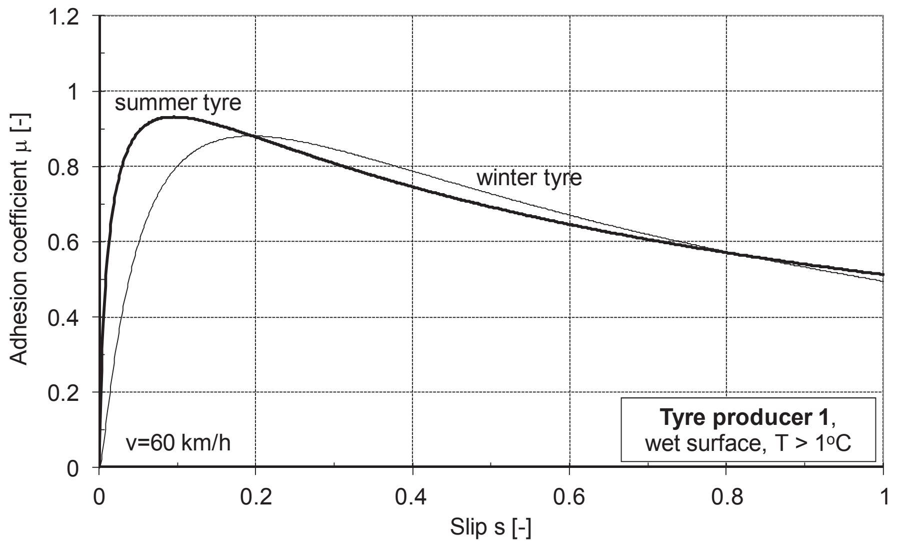


Fig. 7. Adhesion characteristics $\mu(s)$ for summer and winter tyres – positive temperatures

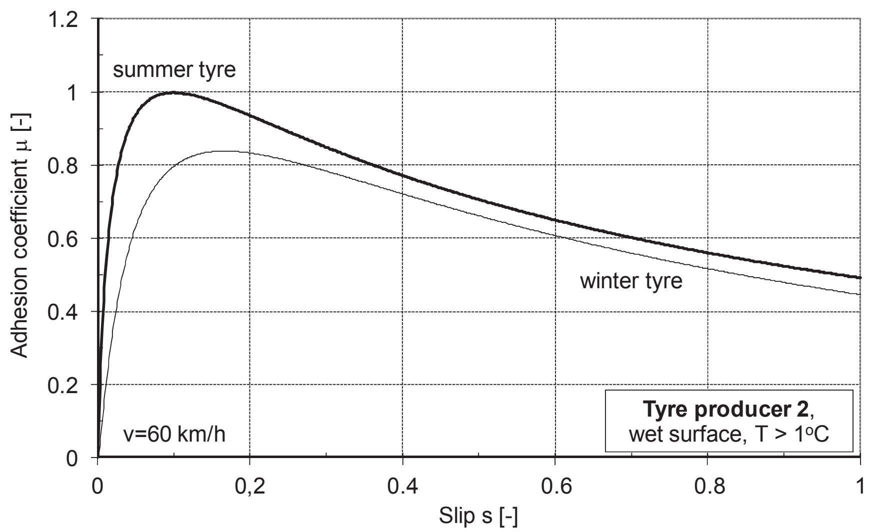


Fig. 8. Adhesion characteristics $\mu(s)$ for summer and winter tyres – positive temperatures

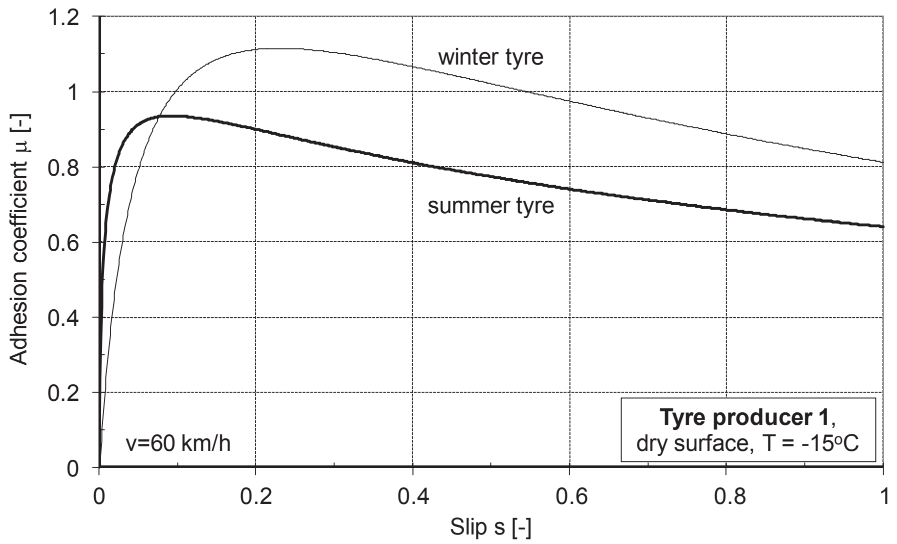


Fig. 9. Adhesion characteristics $\mu(s)$ for summer and winter tyres – negative temperatures

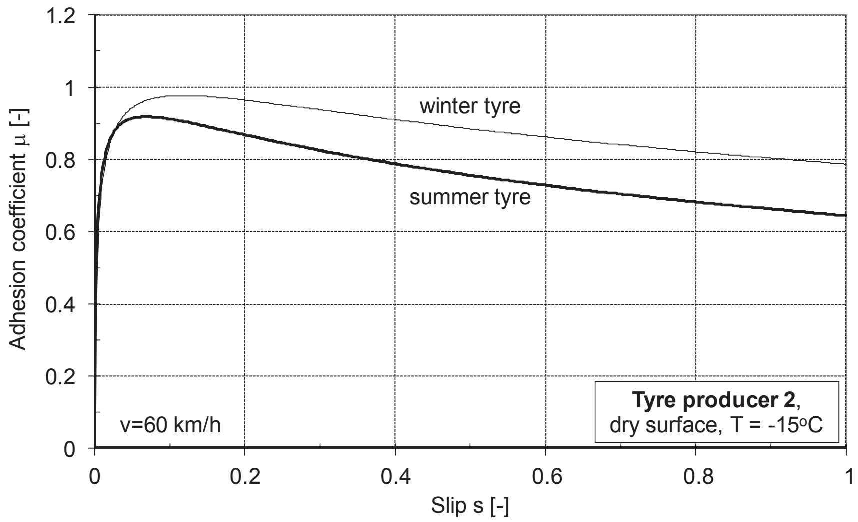


Fig. 10. Adhesion characteristics $\mu(s)$ for summer and winter tyres – negative temperatures

4. Results of the measurements in negative temperatures of road surface

In Tab. 2 are presented the averaged results of the measurements of adhesion coefficients $\mu_o(v)$ for low road surface temperatures (-15°C), prepared for two investigated velocities v (30, 60 km/h) on dry asphalt road surface in the area of Warsaw for both tyre producers.

Tab. 2. Adhesion coefficient $\mu_o(v)$ in negative temperatures; temperature -15°C, dry road surface

tyre producer 1		
v [km/h]	summer tyre	winter tyre
30	0.74	0.88
60	0.64	0.81

tyre producer 2		
v [km/h]	summer tyre	winter tyre
30	0.79	0.86
60	0.64	0.78

Definitely for the low temperatures (-15°C) the winter tyres are characterized by higher, compared to summer tyres, values of adhesion coefficient $\mu_o(v)$.

5. Conclusion

For positive temperatures summer tyres are demonstrating higher values of adhesion coefficient μ_o than winter tyres. It is also taking place in the temperatures close to the zero. Similarly, the peak values of adhesion coefficient $\mu(s)$ are higher for summer tyres. So, a fall in anti-slip properties is not noticed in the temperature about 7°C, often assumed as critical.

For low temperatures (-15°C) the adhesion characteristics of winter tyres are demonstrating higher values of adhesion coefficient practically in the whole range of slip ratio. Furthermore, the winter tyres are reaching the peak values of adhesion coefficient $\mu(s)$ for higher values of slip ratio than summer tyres. It may influence the vehicle motion dynamics [4] and the precision of ABS and ESP systems functioning.

The research was conducted on clean asphalt road surfaces in the range of the temperatures from -15^{o}C to +13^{o}C. For the full assessment of the anti-slip properties of summer and winter tyres it is planned to conduct the investigations in high summer temperatures and in winter conditions on the snow and on ice.

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