RADIAL TYRE DEFLECTION OF ROAD VEHICLE IN DEPENDENCE ON TEMPERATURE

Petr Jilek[1], Ondřej Voltr[2]

Summary: The paper deals with the tyre deflection of the road vehicle in dependence on the temperature. It also processes the issue of inflating a tyre of road vehicle with nitrogen and whether it has noticeable influence to the magnitude of tyre deflection. The paper evaluates the magnitude of deformation of the tyre in dependence on the different temperatures of the vehicle wheel, which has been heated up to a temperature of 80 °C.

Key words: automobile, tyre, pressure, wheel.

INTRODUCTION

The cars are an inseparable part of everyday life and each of us cannot imagine life without them. Reliability, safety and comfort are domains of each car which are taken for granted. Among the most important elements affecting the comfort and safety of a car belong the wheels.

Current car wheels consist of a tyre, a disc, a rim and in some limited cases of a tube and a flap (to protect tube). Difference between wheels for trucks and for passenger cars are primarily in size and shape of the rim. Trucks have flat rims, and cars have deepened ones.

Automobile safety depends on the reliability of all the subcomponents. The most intensive wear falls on the tyres, which are subject to diverse aging. The reliability of the tyres can be increased by perfect maintenance and avoiding overloading. It means that tyres primarily operate with the prescribed level of pressure, use a suitable tread design for the communication and, most importantly, the biggest influence is a driving style. The tyre ensures the transfer of power from the car wheel to the road and vice versa. Therefore, it is appropriate to check the tyre pressure at least once per every 14 days or at any suspicion of pressure drop.

For these reasons, it is suitable to follow the technical documentation and inflating tables that define the load and air pressure for different operating conditions. Under-inflation causes the uneven wearing of the tyre, separation and cracking of the tyre flap. On the

[1] Ing. Petr Jilek, University of Pardubice, Jan Perner Transport Faculty, Department of Transport Means and Diagnostics, Studentská 95, 532 10 Pardubice, Czech Republic, Tel.: +420 466 036 486, Fax: +420 466 036 361, E-mail: petr.jilek@upce.cz
[2] Ing. Ondřej Voltr, University of Pardubice, Jan Perner Transport Faculty, Department of Transport Means and Diagnostics, Studentská 95, 532 10 Pardubice, Czech Republic, Tel.: +420 466 036 463, Fax: +420 466 036 361, E-mail: ondrej.voltr @upce.cz

contrary, over-inflation causes an increase in total hardness of the tyre and thus increases the susceptibility of the puncture.

Current main requirements to tyres:

- minimal rolling resistance,
- minimal weight,
- absorption of shocks and vibrations from road bumps,
- maximal lifetime,
- maximal transmission of power force on any road condition,
- maximal transmission of brake force on any road condition,
- correct transmission of lateral forces with minimal deformation,
- sufficient drainage of water or other impurities from contact surface with the ground.

1. TYRE CONSTRUCTION

Radial tyres

For tyres of radial construction are body ply cords laid at 90 degrees angle in relation to the direction of rotation of the tyre. The cords are anchored around the bead wires. The cord body is circumferentially reinforced by almost inextensible belt. This tyre has better grip to the inequalities, greater absorption of unwanted vibrations and greater contact area with the ground in comparison with bias tyre. The disadvantage of the radial tyres of road vehicles is their lower resistance to mechanical damage in comparison with bias tyres.

Bias tyres

For bias tyres body ply cords are usually laid at angles in the range of 30 to 40 degrees angle in relation to the direction of rotation of the tyre. The ply cords are mutually crossing in the adjacent layers and they also intersect when viewed from above. For both types of tyres are ply cords laid from bead to bead.

The advantage of bias tyres is high stiffness of the sidewall. Therefore, they are very resistant to damage and capable of transmission of high radial loading. The main disadvantage is a bad copying of the road surface.

2. TYRE TEMPERATURE

Warming of the tyre occurs due to the cyclic deformation during the rolling. Considerable amount of heat is transferred to the tyre from the environment by road and by air. Tyre is also simultaneously warmed from the disc, which transmits the heat generated in the wheel brakes during braking of the car. The proper temperature of tyre is very important especially for sport tyres because the adhesion is dependant to the proper temperature. Tyre with lower temperature does not reach the prescribed tyre adhesion. Also when temperature is too high, the tread rubber is degraded and tyre does not reach the prescribed adhesion too. Therefore, it is not convenient to use tyres primarily intended for sport purposes for non-sport purposes and even if they were already partially used. This applies in particular for motorcycle tyres.

3. HEATING OF THE TYRE WITH PURPOSE OF DETERMINATION OF THE CHANGE OF RADIAL STIFFNESS

The experiment uses tyres Bridgestone Turanza with the size 195/55 R15. The default pressure value was 0.28 MPa at 25 °C. Tyre pressure was not adjusted during the measurement.

The tyre was inflated with nitrogen in the first series of measurements. Content of the filled tyre was approximately composed of 98% nitrogen and 2% of other gases, such as residual air in the tyre during its full release.

In the second measurement series, the tyre was inflated with air, which was composed of approximately 78% N_2, 20% O_2, 2% other gases and solid particles.

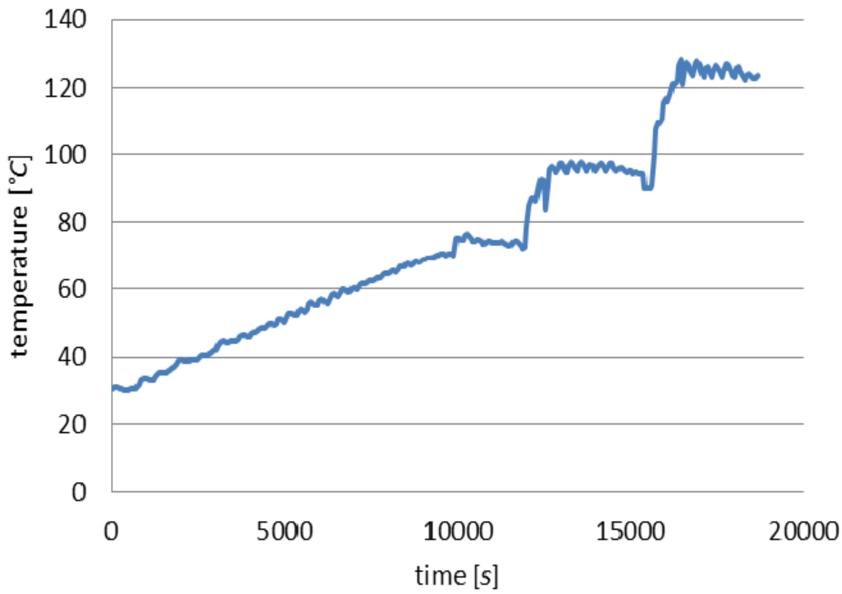

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Fig. 1 – The course of wheel tempering

The wheel was heated in a tempering chamber, while the tempering temperature was observed at the top of this chamber. Due to the drop of the wheel temperature during the assembly, the tempering temperature had to be 20 °C higher than the temperature of realization of the experiment itself. Tempering of the wheel occurred gradually to reach uniform heating of the wheel throughout its volume. The course of tempering is shown in Figure 1.

For both fillings (nitrogen or air) the wheel was always gradually tempered to 30 °C, 50 °C, 60 °C and 80 °C.

During a testing on static adhesor, the surface temperature of the tyre was monitored at various points along its circumference by non-contact thermometer. For better demonstration a thermal imaging camera for scanning temperature field distribution on the wheel was used. The uniformity of heating of the wheel is shown in Figure 2.

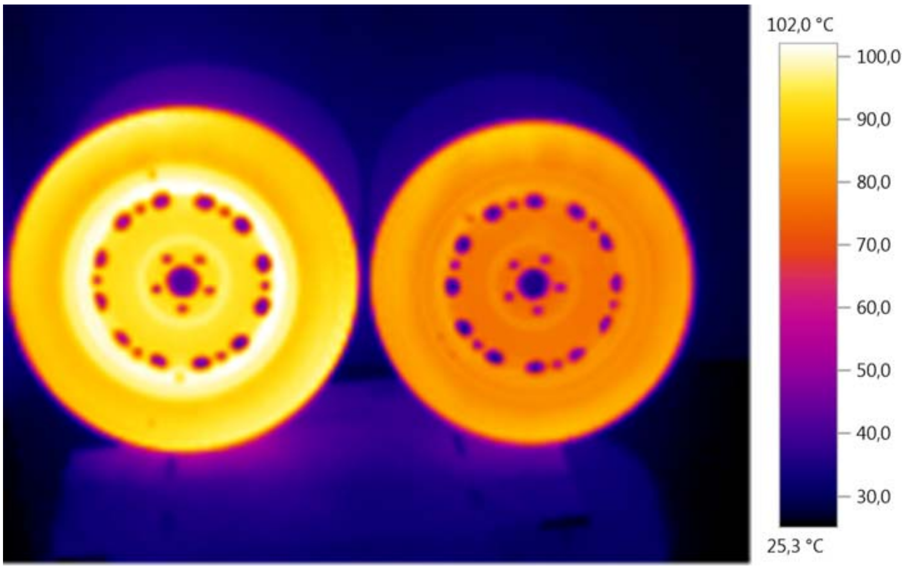

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Fig. 2 – The temperature field distribution on the wheel – tempering chamber

In order to compare with real conditions, the wheel was exposed to sunlight at air temperature 28 °C. Temperature field distribution is evident from Figure 3, where is obvious that the vehicle wheel can be warmed to 90 °C, and that all only under the action of sunlight.

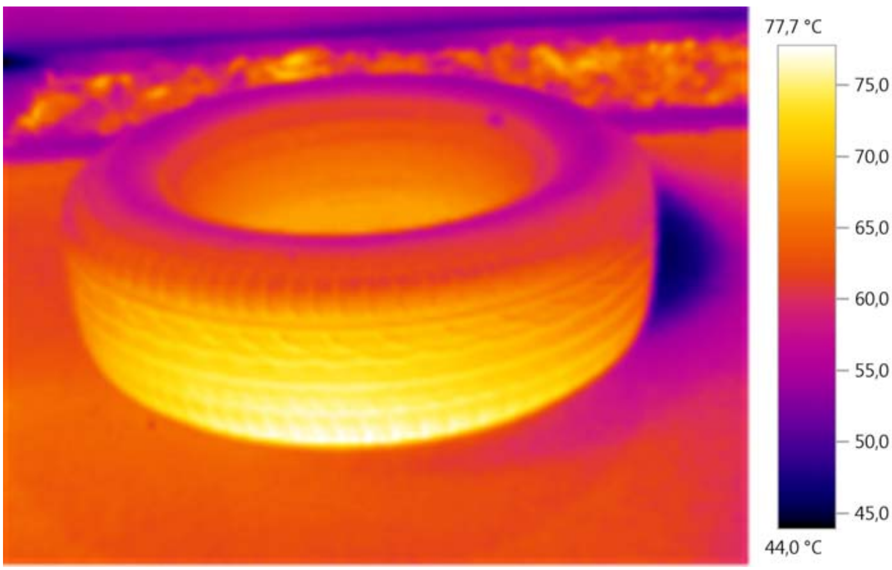

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Fig. 3 – The temperature field distribution on the wheel – sunlight

4. THE MEASUREMENT OF THE RADIAL TYRE DEFLECTION

The change of the vertical load of the wheel was realized on a static adhesor. The wheel was at rest position and without rotation. The size of the radial reaction was controlled hydraulically. The resulting value of the size of the radial load was determined by using one platform of a mobile wheel scales. Yet the resulting load value is expresses in Newtons. Load increment is 500 N, which is added repeatedly till to a maximum value of 10.5 kN. To reduce of heat transfer between the steel surface of measurement platforms and the contact surface of the tyre tread a thermal insulation pad was placed.

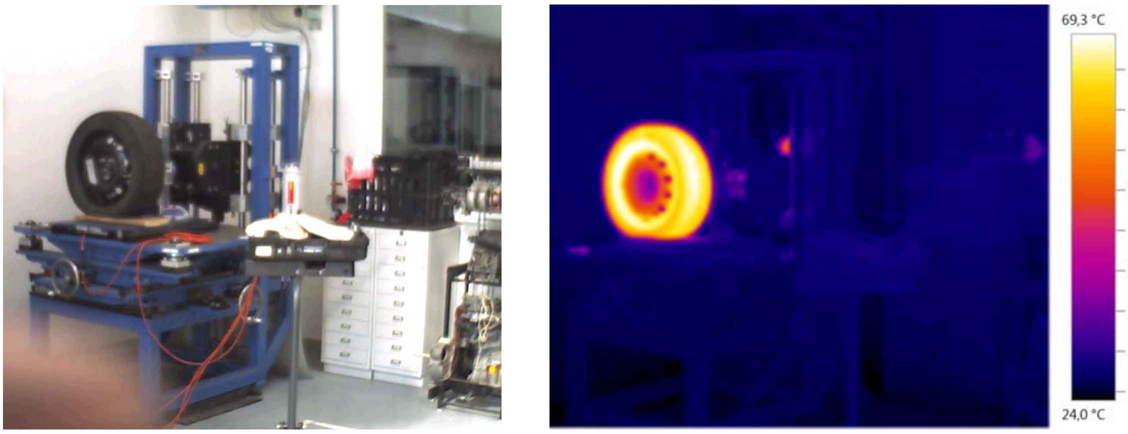

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Fig. 4 – Measurements of the radial deformation of the wheel on a static adhesor

Measurements of the radial deformation of the wheel (see Figure 4.), i.e. tyre, were realized by using digital altimeter at defined load of the wheel. The default deformation, which equals to zero, has been treated as the first contact of the wheel with an insulating pad, when the value of the radial load was 20 N.

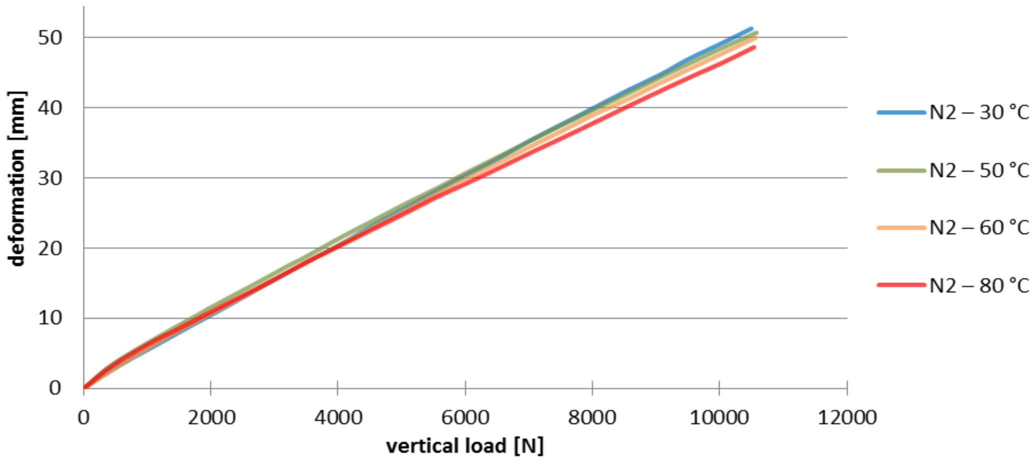

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Fig. 5 – Radial deformation of the tyre – nitrogen

The courses of radial deformation of the tyre filled with nitrogen and air are shown in Figure 5., i.e. Figure 6.

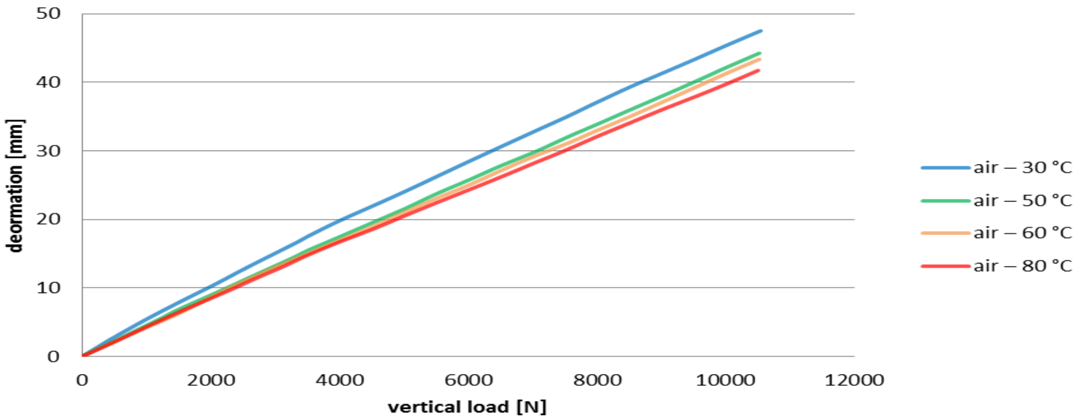

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Fig. 6 – Radial deformation of the tyre – air

When tyre was filled with nitrogen to an initial pressure of 0.2 MPa the static radial deformation of the tyre at 30 °C is described by equation (1). The equation (2) applies for the temperature of 80 °C.

$$y = -3E\text{-}08x^2 + 0.0052x + 0.1486 \quad (1)$$

$$y = -5E\text{-}08x^2 + 0.005x + 0.8307 \quad (2)$$

where:

y – is static radial deformation of the tyre [mm],

x – is radial load of the tyre [N].

The static deformation of the same tyre but inflated with air to the pressure of 0.2 MPa at 30 °C is described by equation (3), and the temperature of 80 °C is described by equation (4).

$$y = -5E\text{-}08x^2 + 0.005x + 0.3308 \quad (3)$$

$$y = -2E\text{-}08x^2 + 0.0042x + 0.1584 \quad (4)$$

Values of radial deformation of the tyre subjected to radial load 10 kN are shown below for example. Deformation of the tyre filled with air is in the range from 41.72 to 45.43 mm, while for nitrogen filled is the difference of the deformation in the range from 46.42 to 49.16 mm.

CONCLUSION

The elasticity of rubber increases with increasing temperature. Rising temperature of the tyre causes that the flexibility of rubber increases, but at the same time pressure in the tyre increases too. Besides the rubber the tyre is composed of steel cords, reinforcements and textile fibres. So the rigidity of the tyre is limited and cannot be determined easily, therefore it must be determined experimentally.

With increasing temperature of the wheel the pressure inside the tyre rises due to expansion of gases. This has a dominant effect on tyre behaviour.

The change of the rigidity of the vehicle wheel, i.e. tyre, thus depends on the temperature of the tyre and the type of the filling medium. The rigidity of the tyre increases with increasing temperature and vice versa. With increasing temperature the static change of tyre stiffness is lower for nitrogen filled wheel than for tyre filled with air. Control over the car changes with increasing temperature of the tyres. However, this change is so low that in normal circumstances on the road the driver does not recognize the difference between tyres filled with nitrogen and air. Behaviour of the wheel in dynamic mode is the subject of further research on DFJP through the use of dynamic adhesor of tyres.

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