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Tire Experiments on Static Adhesor for Obtaining the Radial Stiffness Value

Jan Krmela / *Libor* Beneš / *Vladimíra* Krmelová

RESEARCH ARTICLE

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Abstract

The paper deals with static experiments of tires on a test machine for tires – static adhesor. The radial stiffness value of tires is obtained from the radial deformation characteristics from experiments on static adhesor. The new formula for radial stiffness value is described in the paper. This formula takes into account more real operating conditions during the loading of tires. The paper describes static experiment of selected tire on static adhesor and its results. We have compared three different tires with different radius and profile numbers. Knowledge about stiffness and information from tire experiments is necessary for the verification analyses between experiment data and computational results from computational modeling by Finite Element Method.

Keywords

Long-fibre composite · tire · static experiment · static adhesor · radial stiffness

Jan Krmela
Faculty of Industrial Technologies in Púchov, University of Alexander Dubček in Trenčín, Púchov, Slovak Republic
e-mail: jan.krmela@fpt.tnuni.sk, jan2.krmela@post.cz

Libor Beneš
Faculty of Mechanical Engineering, Department of Materials Engineering, Czech Technical University in Prague, Prague, Czech Republic

Vladimíra Krmelová
Faculty of Industrial Technologies in Púchov, University of Alexander Dubček in Trenčín, Púchov, Slovak Republic

1 Introduction

The paper deals with the specific composites with elastomer matrix and steel cord reinforcement. These composites are typical for a tire-casing for transport means. The experiments of tires are needed for verification analyses between computations and test data. The paper is oriented on static experiments on a special test machine for tires – static adhesor.

2 Static adhesor

Static adhesor is a special test machine for tires for passenger cars (Fig. 1) at Faculty of Industrial Technologies in Púchov, Slovak Republic. On the static adhesor is possible to obtain outputs as:

- Character of deformation;
- Radial deformation characteristic;
- Radial stiffness value;
- Contact patch – size and shape with contact pressure in contact patch by a special indicating film.

On the static adhesor it is possible to load the tires up to the value of approximately 1 ton. It is possible to test the tires from the radius of tire R13 to R18 and with maximum width of tire-carcass 235 mm. The experiments are performed by special standards for tires (ČSN 63 1511; ČSN 63 1001-4; ČSN 63 1502; ČSN 63 1509 & ČSN 63 1554). Overall three measurements were performed on different locations around the perimeter of the tires. The load speed of tire during experiments were from 0.8 to 2.5 mm/s by ČSN 63 1511, which describes determination of static radial stiffness and experimental conditions for testing of tires.

This paper compares results from experiments on the static adhesor on three tires with different radius, width and profile numbers: Matador 165/70 R13 (Fig. 2) with high profile number and two tires with low profile numbers Bridgestone 205/55 R16 (Fig. 2 right) and Continental 225/50 R17 (Fig. 3). These tires were selected by submitter. The inflation pressure was 2.5 bar, only tire 205/55 R16 had lower pressure 2.3 bar. The tire 165/70 R13 has load index (LI) 412 kg, tire 205/55 R16 has LI 615 kg and 225/50 R17 has LI 665 kg.

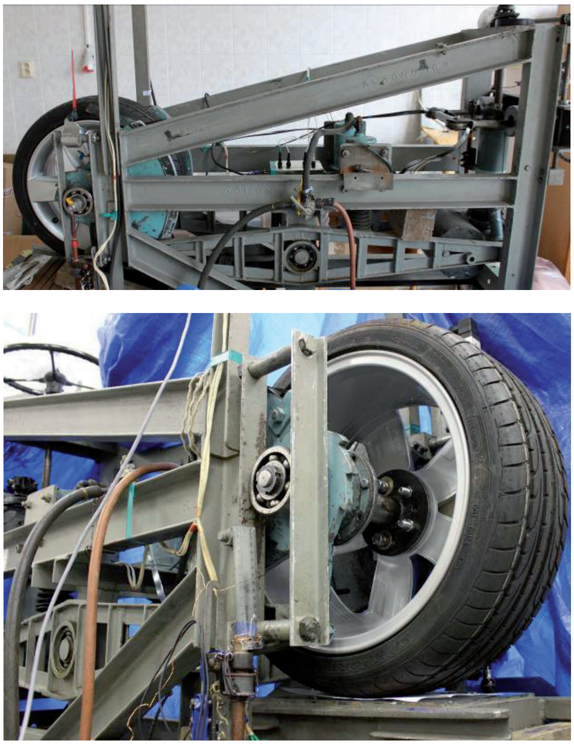


Fig. 1. Static adhesor with measured tire

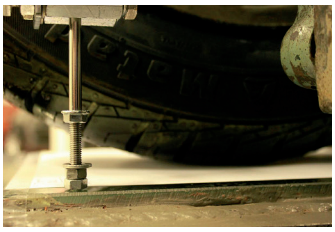
Fig. 2. Matador 165/70 R13 *(left)*, Bridgestone 205/55 R16 *(right)*

Fig. 3. Continental 225/50 R17

3 Character of deformation

Deformation of the tire-casing 165/70 R13 in contact with the surface plate was recorded during the experiment and is shown in Tab. 1. The deformation of tire-casing for 100% of LI is c. 21.5 mm. Deformation of the tire-casing 205/55 R16 is shown in Tab. 2. The deformation for 100% of LI is 26.5 mm. The tire 225/50 R17 has deformation equal c. 25.0 mm for 100% of LI (Tab.3).

Tab. 1. Deformation of the tire casing 165/70 R13



0 % of LI

75 % of LI

100 % of LI

125 % of LI

Tab. 2. Deformation of the tire casing 205/55 R16

0 % of LI

75 % of LI

100 % of LI

125 % of LI

Tab. 3. Deformation of the tire casing 225/50 R17

0 % of LI

75 % of LI

100 % of LI

125 % of LI

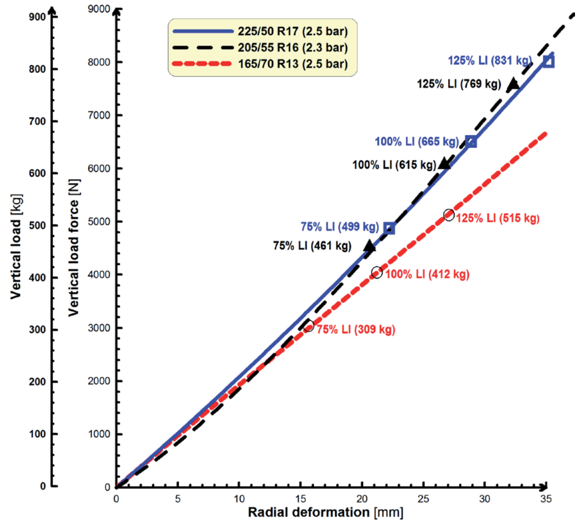


Fig. 4. Radial deformation characteristics

4 Radial deformation characteristic

Radial deformation characteristic (Krmela and Pastorek, 2012) depends on the vertical force that presses the inflated tire against a rigid surface perpendicular to the direction of loading, and on the vertical deformation of the casing which is generated by the loading between the wheel rim and the surface at the place of the tire surface contact (Krmela, 2008).

The slip characteristics of the tire, which is also an important characteristic of the tires, can also be measured on the static adhesor. The flat glass surface as special surface is use for experiments.

The radial deformation characteristics for selected tires are shown in Fig. 4. The radial deformation characteristic for tire 225/50 R17 for different inflation pressure 2.9 bar is shown in Fig. 5.

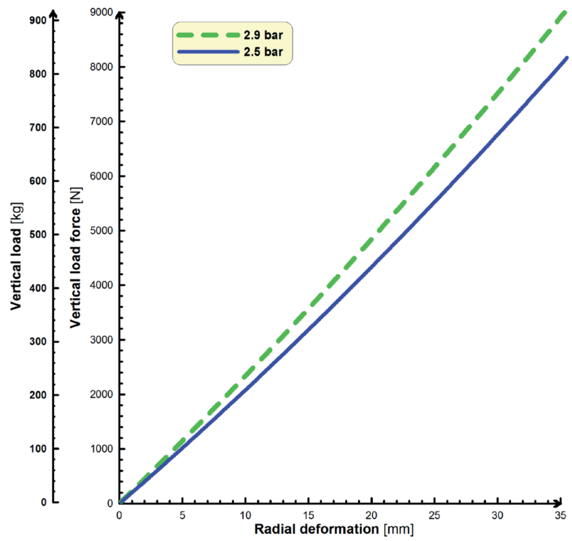


Fig. 5. Radial deformation characteristics of 225/50 R17 for different pressures

5 Radial stiffness

The radial stiffness, which is obtained from the radial deformation characteristic by calculation, is an important parameter entering the calculation of entire cars, because the stiffness parameter replaces the whole tire.

The standard ČSN 63 1511 defines the radial stiffness from the radial deformation characteristic by using a computational relationship, which is determined by points corresponding to 75% and 125% of LI. Based on long-term experiments the author Krmela adjusted the given computational relationship from the standard using a modified computational relation (Krmela et al., 2012). This modified equation (1) takes into account more real operating conditions during the loading of tires. Tires are loading approximately 75% of LI.

$$S = \frac{F_{(125\%\ of\ 0.75\ LI)} - F_{(75\%\ of\ 0.75\ LI)}}{x_{(125\%\ of\ 0.75\ LI)} - x_{(75\%\ of\ 0.75\ LI)}}\ [\text{N/mm}], \qquad (1)$$

where S [N/mm] – radial stiffness;
$F_{(125\%\ of\ 0.75\ LI)}$ [N] – vertical force for 125% of 0.75 LI;
$F_{(75\%\ of\ 0.75\ LI)}$ [N] – force for 75% of 0.75 LI;
$x_{(125\%\ of\ 0.75\ LI)}$ [mm] – radial deformation of tire-casing for 125% of 0.75 LI ($F_{(125\%\ of\ 0.75\ LI)}$);
$x_{(75\%\ of\ 0.75\ LI)}$ [mm] – deformation for 75% of 0.75 LI ($F_{(75\%\ of\ 0.75\ LI)}$).

On the basis of the standard ČSN 63 1511 and the equation (1) the radial stiffness of the individual measurements was determined. The radial stiffness of tire 165/70 R13 is c. 185 N/mm by equation (1). The value of the stiffness for tire 205/55 R16 is 251 N/mm. The tire 225/50 R17 has stiffness c. 240 N/mm.

The radial stiffness depends on inflation pressure of tire. It is a fact that with the increasing inflation pressure, the radial stiffness increases. Standard stiffness values for modern tire for passenger cars are 200-320 N/mm.

6 Contact patch

Simultaneously prints are made using "ink print" method and pressure indicating FUJI Prescale® films (for tire used Ultra Low Film LLLW with range 2-6 kg/cm^2). Pressure indicating films are strongly sensitive to moisture.

The contact patches by "ink print" method for tires for 100 of LI for the inflation pressure 2.5 bar are in Figs. 6 and 7.

The contact patch obtained by indicating film for tire 205/55 R16 for 320 kg load (approx. 50% of LI) and 2.3 bar is on the Fig. 8 as sample output from indicating film analysis. Deformation for this vertical loading is approx. 16.5 mm. From the print the analysis of the distribution of the contact pressure in the contact patch can be provided. The average contact pressure in contact patch for concrete tire is 3.7 bar.

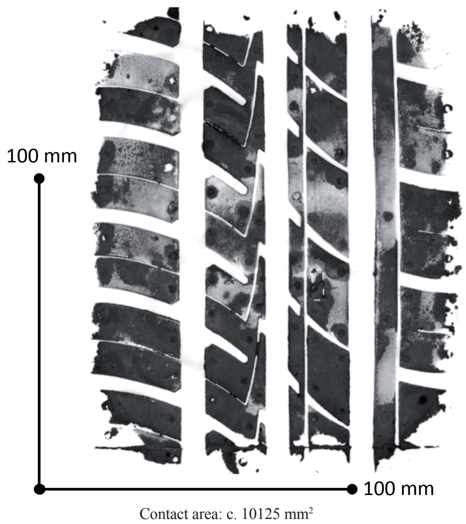


Fig. 6. Contact patch by "ink print" method for tire 165/65 R13 for 100% of LI and 2.5 bar

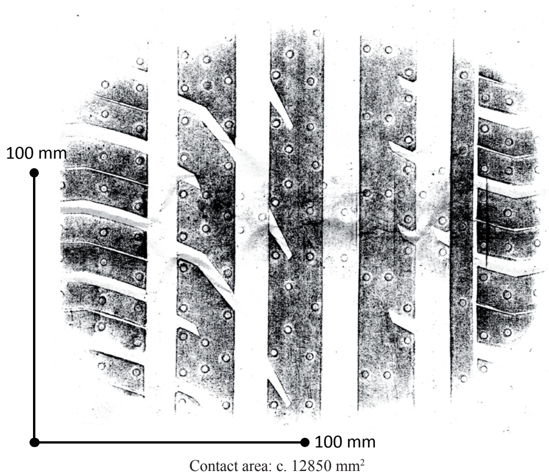


Fig. 7. Contact patch by "ink print" method for tire 225/50 R17 for 100% of LI and 2.5 bar

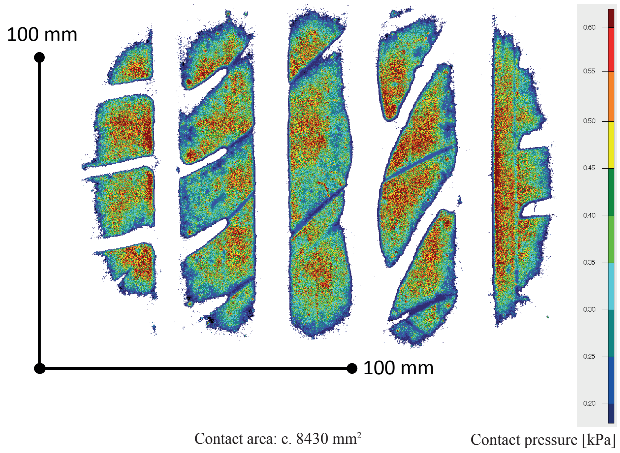


Fig. 8. Contact patch with distribution of contact pressure by indicating film analysis for tire 205/55 R16 for 50% of LI and 2.3 bar

7 Conclusion

From the radial deformation characteristics it is possible to acquire the values of the radial stiffness, which can be used as a replacement of the whole tire in the dynamic calculations of complete vehicles.

In this paper the new formula for calculating of value of radial stiffness was applied.

The knowledge about contact patches and contact pressures is necessary for verification analyses between experiments and computations of tires by Finite Element Analyses.

The continued research work of authors will be comparing radial stiffness of tires with the same radius R 17 and manufacturer Continental. Variable parameters are only profile number and width.

Maximum of vertical loading on the static adhesor is c. 1 000 kg. Some tires with low load index (e.g. tire 165/70 R13 where maximum load LI is only 412 kg) are possible to test from 0 to 240% of LI and those tires for small car can be overloaded with great deformation. Low-profile tires with maximum load index c. 102 are possible to test on the static adhesor.

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