ROLLING RESISTANCE AS A PARAMETER OF A TYRE QUALITY

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SUMMARY

The purpose of this paper is to show to a reader an integrated knowledge about tyre rolling resistance according to measured values of RR coefficient of tyres with different construction and material composition. Additional measurements of tread print are mentioned.

Keywords: tyres, rolling resistance, tread pattern

1. INTRODUCTION

The rolling resistance (RR) is one of the most important parameters of quality evaluation of tyres. The rolling resistance is defined like the energy used up for a length unit of trajectory during moving of tyre (Fig.1). Hysteresis losses, resistance of aerodynamics and friction in contact location of road and tyre have influence on a car moving. With decreasing of rolling resistance coefficient is possible to decrease of fuel consumption. Values of rolling resistance are in relation to velocity, loading, temperature and pressure. Rolling friction generates heat and sound energy, as mechanical energy is converted to these forms of energy due to the friction. Pauwellusen presents in his work [1] a theoretical tyre model. The tread and belt's properties are characterized by stretched string and brush elements. Rolling resistance is also the parameter for fuel consumption determination. Tyre manufacturers aim is to reduce the RR in order to improve fuel economy [2]. Axel Friedrich presents in his work [3] the results of competitor's tyres measurements. The rolling resistance was measured according to standard ISO8767. The

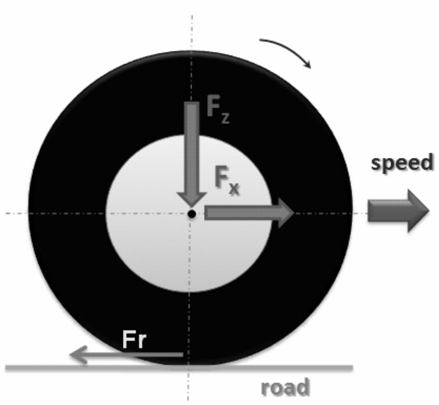

Figure 1. Rolling resistance explanation

general parameter criteria for the measured tyres is cost-by lever not higher than 72 dB, RR coefficient C_R lower than 1.1% (for winter tyres) and 1.2% (for summer tyres).

2. THEORY

2.1. Rolling resistance

Rubber is a viscous-elastic material: as it deforms, a fraction of the energy is stored elastically, but the remainder is dissipated as heat. The standard units of rolling resistance are Joules per meter (J/m) or simply Newtons (N), and rolling resistance of a free rolling tire can therefore be considered as a force that opposes vehicle motion R. The improvement of RR 10% means fuel savings ~ 0.5 to 1.5% for passenger cars [4]. Values of rolling resistance are in relation to velocity, loading, temperature and pressure. Like authors in [5], we've also measured the RR according to standard. It should be also considered that the RR of a vehicle could be higher than a measured on a smooth drum in a laboratory because of road roughness. Vibrations of car, caused by road roughness, lead to energy dissipation due to damping and friction. Furthermore a dynamic vertical deflection of tyres causes hysteretic losses in the rubber material and frictional losses in the tyre contact with a road due to microslip. Also additional deformation should be considered.

To better quantify and understand the contribution of RR to fuel consumption is defined so called Return Factor, also referred like energy ratio. It is represents by ratio of reduction of fuel consumption and reduction of RR in % [6].

The coefficient of rolling resistance is defined by relation

$$C_x = \frac{F_r}{9.81.Q_r}, \tag{1}$$

where Q_r is radial load and F_r, rolling resistance power, is expressed by

$$F_r = F_x\left(1 + \frac{r_d}{R}\right). \tag{2}$$

r_d is dynamic radius of tyre and R is a radius of laboratory testing drum.

The RR was measured at speed 50, 90, 120 a 150 km/h. The RR value is increasing with the increasing of speed.

The Fig. 2 shows a tyre parts contribution to total rolling resistance of tyre.

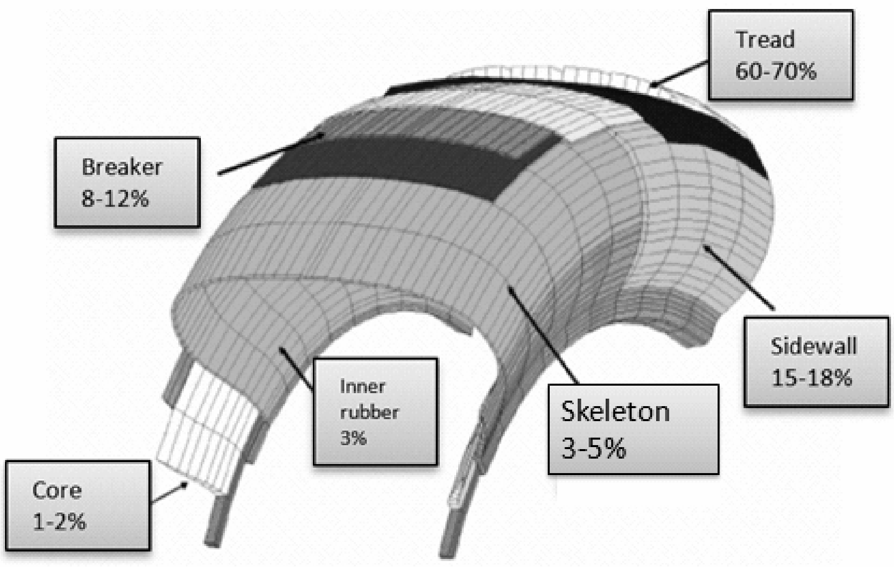

Figure 2. Tyre parts contribution to RR

2.2. Tyre construction

The investigation of tyre parameters is focused on steel belt angle arrangement and changing of core material. The steel belts are placed under a tread. It is created steel wires under acute angle. This internal part of tyres optimizes a directional stability and evidently the rolling resistance. For a comparison the four different tyres (wire angles 20°, 23°, 25° and 27°) were compared. The breaker contributes to total RR with its 12%. A bead core function is keeping the tyre firmly on the rim. Its contribution to total RR of a tyre is approximately 2% - the smaller one.

2.3. Tread print

A shape of a tread print is closely connected with rolling resistance. According to Goodyear patent WO98/25775 is defined so called footprint shape factor FSF. The optimal value is approx. 1.3. The higher value FSF the handling, RR and tread wear is better. The lower value of FSF the noisiness is decreased.

The test is based on a simply method. The prepared tyre is loaded on a special pressure foil. The foil consists of two layers. The layer 2 stores red pigment. After pressure application the pigment is printed on the second foil. It is clearly shown on the Fig. 3.

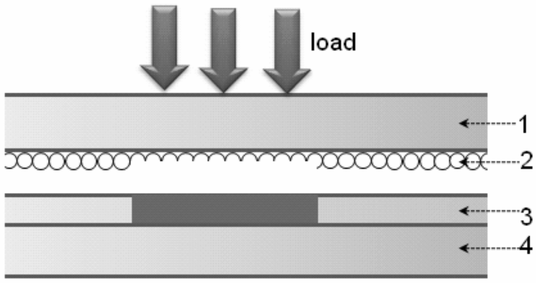

Figure 3. Foils. 1 – polyester, 2 – layer with a pigment, 3 – layer sensitive on pigment, 4 - polyester

3. RESULTS

The Tab. 1. presents the measured values of three rubber mixtures used for modified tyres. The complex Young modulus was measured in dynamic mode [7]. The resonance frequency is f_0, the absolute value of cpx. Young modulus is $|E^*|$. For example contents of sulfur are also mentioned in this table. The Tab. 2 completes material parameters of rubber mixtures. It is presented by modulus 300, strength and elongation. The Fig. 4 shows a real footprint of a tyre.

Table 1.Complex Young modulus

	I. mixture	*II. mixture*	*III. mixture*
f_0 *[Hz]*	*1214*	*1722,41*	*919,066*
$\lvert E^*\rvert$ *[MPa]*	*43,6*	*89,6*	*25,5*
Sulfur content	*3.5 dsk*	*4.0 dsk*	*2.0 dsk*

Table 2. Other physical parameters of used rubber compounds

Parameters of rubber compounds	*Core comp. I*	*Core comp. II*	*Core comp. III*
Modulus 300% (MPa)	*15.0*	*12.0*	*12.8*
Strength (MPa)	*16.2*	*16.5*	*14.9*
Elongation (%)	*340*	*285*	*255*

The Tab. 3 shows the calculated RR coefficient according to relation (1).

Table 3. The measured values of C_x

Steel belt angle	*Rolling resistance ratio C_x*	*Steel belt angle*		*Rolling resistance ratio C_x*
20°	*0.0102*	*23°*	*I*	*0.0097*
23°	*0.0101*		*II*	*0.0098*
25°	*0.0099*			
27°	*0.0097*		*III*	*0.0096*
Modification of breaker		*Material modification of core*		

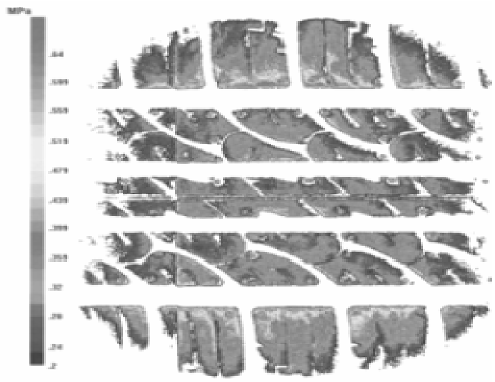

Figure 4. Real tread print for breaker angle 25°.

4. CONCLUSIONS

- The rubber mixture II for tyre core shows the most suitable parameters for that purpose.
- In general, the contribution of core to total RR is small. We should consider the best material properties of material, because of high loading, not only the value of C_x. We have to change other tyre part and therefore improve the RR.
- We can conclude that with increasing of the breaker angle the RR ratio decreases. These results are presented in tab. 3. With the increasing of steel belt angle the tyre appears "softer", its deformation during run is bigger, it can better adapt to road roughness. The deduction of these results is that with higher deformation of tyre the RR is decreased. But it is valid only for construction or rubber mixtures changes. It is not valid for a tyre under proper inflation. The smaller inflation leads to RR increasing. It means the improvement of fuel economy and comfort in car.
- The mentioned tread print is useful for better understanding of tread load distribution. The not even distribution leads to higher RR or to not proper wear of a tread.

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