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MEASUREMENT BY A CYLINDER TEST STAND AND TYRE ROLLING RESISTANCE

Vladimír Rievaj[1], **Peter Faith**[2], **Andrej Dávid**[3]

[1, 2] *University of Žilina, Faculty of Operation and Economics of Transport and Communications, Department of Road and Urban Transport, Univerzitná 1, 010 26 Žilina, Slovakia*

[3] *University of Žilina, Faculty of Operation and Economics of Transport and Communications, Department of Water Transport, Velky Diel, 010 26 Zilina, Slovakia*
E-mail: [1] *rievaj@fpedas.utc.sk,* [2] *fajth@fpedas.utc.sk,* [3] *andrej.david@fpedas.utc.sk*

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Abstract. Sometimes it is necessary to test how repair affects the properties of the car. These tests are carried out using a cylinder test stand. During the test the tyre is rolling between two cylinders of a small diameter. The question arises whether the rolling resistance of the tyre is the same as the rolling resistance when the wheel is rolling on the plane. If it is not the same what is the reliation between tyre resistances in these two cases? It is an important answer because the change of rolling resistance can affect consumption, the highest speed, engine power and other results of measurement. The paper gives the answer to these questions and describes the method of getting this information.

Keywords: tyre, rolling resistance, cylinder test stand MAHA LSP 2000, power.

1. Introduction

After car repair it is sometimes necessary to do some tests [1, 2]. They provide us with the information how new adjustment affects the behaviour and properties of the car. Previously these tests were carried out by the driving test, however, it wasn't sufficiently effective. It was hazardous due to the accident possibility, it took a long time and the results were not exact. Consequently, cylinder test stands are used to carry out these tests nowadays. The car doesn't need to leave the workshop and tests bring information about the engine power, the fuel consumption or the useable force for driving by predefined driving resistance. If we want to use these results practically, it is useful to know what is the dependence of tyre rolling resistance. During the test the wheels are rolling between two cylinders of a small diameter (Fig 1).

We can suppose that the rolling resistance is higher than the resistance when the tyre is rolling on the plane. The reasons for this assumption are as follows:

- Normal force Z_k is divided between two forces named F_1 and F_2 (see Fig 1). We can write the formula (1) to define their intensity:

$$F_1 = F_2 = \frac{Z_K}{2 \cdot \cos\alpha}. \qquad (1)$$

The symbols are clear from Fig 1. We can define angle α by using a isosceles triangular $O_{v1}O_{v2}O_k$.

- Tyres have to be adopted twice.

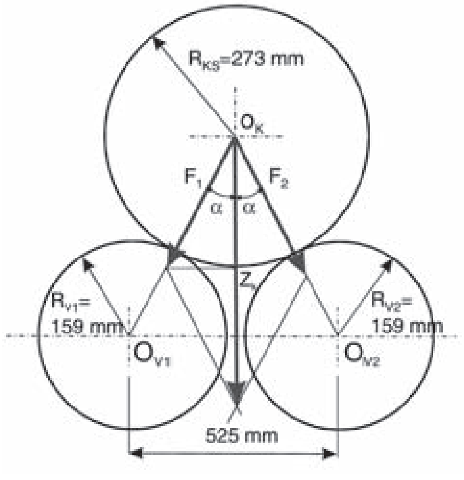


Fig 1. Distribution of normal onerous force Z_k between cylinders of a cylinder testing stand

Consequently the tyre rolling resistance on the plane is not the same as the one on the cylinder testing stand. What is the dependency between the tyre rolling resistances in these two cases? To answer the question specified above we have to do the measurement of the rolling resistance in both cases and to compare them.

The intensity of the tyre rolling resistance on the plane is detected by a drum stand. The diameter of the drum is 1591, 1707 or 2000 mm. The conditions for this measurement are determined by STN. The manufacturer is obliged to do measurement for each tyre.

To define the tyre rolling resistance in case according to Fig 1 we can use a cylinder testing stand MAHA LPS 2000. It offers the programme KONSTANTE GESWINDIGKEIT to us. Using this program cylinder testing stand MAHA LPS 2000 is simulating the ride on a straight plane at a constant speed. The stand keeps the set point of the speed by a whirling brake. This brake spends overlapping power to the wheels and the testing state displays its intensity. It can be used for rolling resistance measurement.

If we deliver the constant power to the wheels the overlapping power will be constant as well. When we change the normal onerous force the rolling resistance will be changed (at the same time) too. The overlapping power on the wheels will be also changed. The range of its change is equal to the change of the rolling resistance power.

The left and the right pair of the cylinders of the cylinder testing stand MAHA LPS 2000 are coupled by a crankshaft with two joints. This coupling allows us to construct the equipment in Fig 2. The right side is used for input of the constant power. The left side is determined for the variation of the wheel onerous force that affects the change of the tyre rolling resistance.

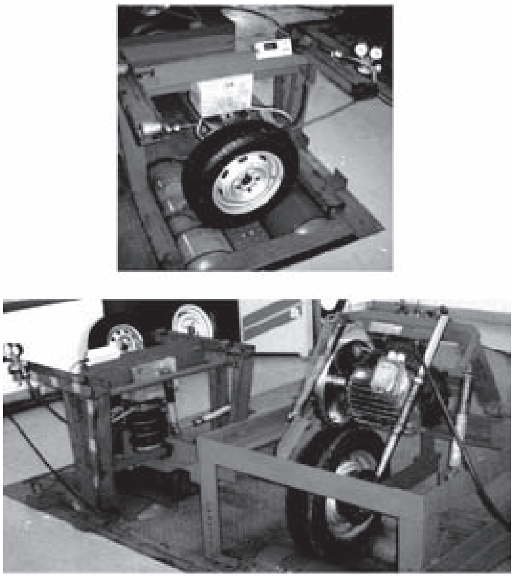


Fig 2. The left and the right side of MAHA 2000 LPS superstructure

2. The right – forced side

An asynchronous electric motor with the power of 10 kW was used for driving. Power was transferred to the wheel by a friction-gear as we can see on the right side of Fig 2. The friction-gear was located on the rotor of the electric motor. It allowed us to change the measuring speed by the replacement of the friction disk of a different diameter. The friction-gear was held down to the driving wheel by the weight of the motor. It guarantees that force is stable. So the rolling resistance developed by it is stable too.

The incoming power is given by the torque of the electric motor and by revolution. The invariance of the revolution is guaranteed by the programme KONSTANTE GESWINDIGKEIT. We can calculate the electric motor moment by multiplying force F [N] that is holding electric motor stabile by arm L_F [m]. Because arm L_F is permanent, the incoming power is permanent, if force F is not changed.

The rolling resistance is changed together with the temperature of the tyre. It is therefore necessary to warm up the tyre to the permanent temperature before starting the measurement by rolling at the normal onerous force for half an hour. It warrants the stability of the rolling resistance and the efficiency of power transfer.

The change of the supplied power can be caused by the change of the uprightness to the axle of stand cylinders, too. Its stability was achieved by a fixed axis.

3. The left – measured side

The part for the measurement must allow the exchange of the tyre. It must guarantee their uprightness to the axle of the cylinders and variation of normal onerous force too. The construction according to the left side of Fig 2 fulfils all these requirements. The construction of the pivoted half axle doesn't allow to change the wheel geometry. It was supplemented with the shock absorbers for safety and quiet tyre rolling. The normal onerous force was involved by the air spring. It can be converted by the change of the air pressure.

4. Measurement

The following conditions for measurement were observed:

a) The tyre was warmed up to the operating temperature,

b) The measured tyre was in the unload condition (onerous force = 0) and the current was turned on. When the equipment reaches the predefined speed the power measured by MAHA LPS 2000 is the same as the supplied power by the right side of the equipment,

c) The normal onerous force (left side of the equipment) was increased to the required value. At that time the power was readout,

d) The difference between the power measured according to b) and according to c) is the power necessary to overcome the rolling resistance,

e) The stability of the incoming power was controlled by the stability of force F as it was explained above,

f) In the half-way of the measurement the measured tyre was released and the power was compared with the result by point b). The powers must be equal.

We can calculate rolling resistance F_R [N] according to the formula (2):

$$F_R = \frac{P_o - P_z}{v}, \qquad (2)$$

where P_o – the power measured by point b), [W], P_z – the power measured by c), [W], v – speed of rolling [m/s].

We can calculate the rolling index of resistance coefficient by the formula:

$$f = \frac{F_R}{F_z}, \qquad (3)$$

where F_R is rolling resistance calculated by the formula (2) [N], F_z is normal onerous force on the measured wheel [N].

5. The measurement results

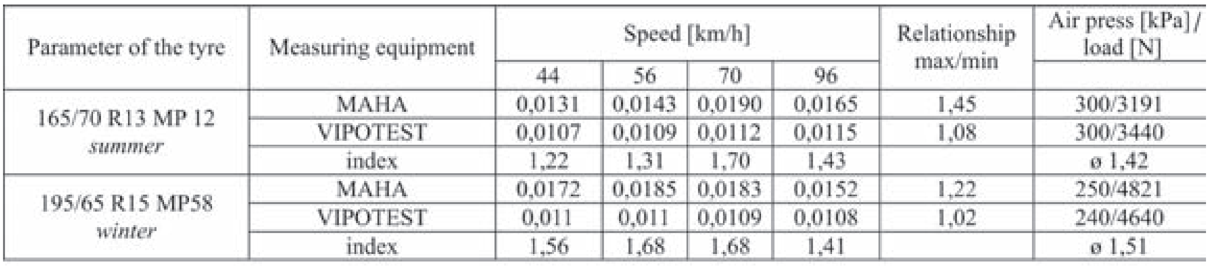
Tyres manufactured by MATADOR Púchov, Inc. were used for the measurement, see Table 1.

The measurement results are displayed in Table 2 and for graphs see Fig 3 and 4. The graphs contain the curves constructed by the results of the testing

Table 1. Tyres used for measurements

Parameter	Design	Load index (LI)	Speed index (SI)	DOT
165/70 R 13	MP 12	79 (437 kg)	T (190 km/h)	0603
195/65 R 15	MP 58	91 (615) kg	H (210 km/h)	4902

Table 2. The value of the index of the rolling resistance f with the air pressure in the tyre and the normal onerous force is approximately equal



Parameter of the tyre	Measuring equipment	Speed [km/h]				Relationship max/min	Air press [kPa] / load [N]
		44	56	70	96		
165/70 R13 MP 12 *summer*	MAHA	0,0131	0,0143	0,0190	0,0165	1,45	300/3191
	VIPOTEST	0,0107	0,0109	0,0112	0,0115	1,08	300/3440
	index	1,22	1,31	1,70	1,43		ø 1,42
195/65 R15 MP58 *winter*	MAHA	0,0172	0,0185	0,0183	0,0152	1,22	250/4821
	VIPOTEST	0,011	0,011	0,0109	0,0108	1,02	240/4640
	index	1,56	1,68	1,68	1,41		ø 1,51

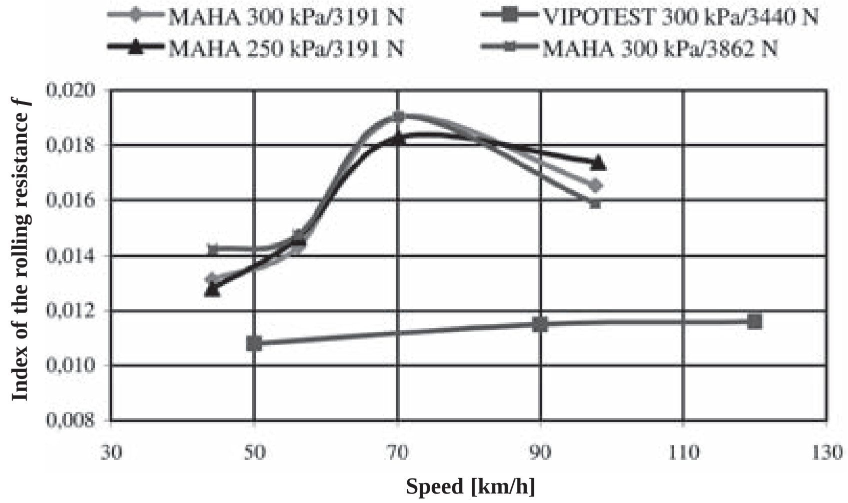


Fig 3. Measurement results – index of the rolling resistance (Tyre 165/70 R13 MP12)

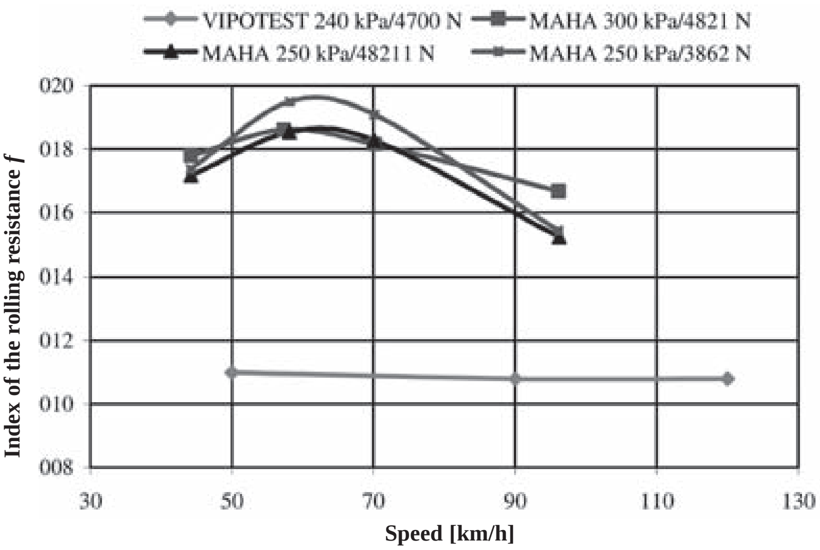


Fig 4. Measurement results – index of the rolling resistance (Tyre 195/65 R15 MP58)

office VIPOTEST and by the results received according to the above described methods. Measurement was done for different air pressure in the tyre and different normal onerous forces. The accuracy of MAHA stand is ± 2 % of the measured value.

6. Conclusions

When we compare the index of the rolling resistance of the tyre measured by VIPOTEST by equipment Hasbach to the results measured by equipment MAHA LPS 2000 we can state:

- Winter tyres show higher growth of the index of the rolling resistance than summer tyres (row index),
- The maximum growth of the index of the rolling resistance was indicated between speeds 56 km/h and 70 km/h,
- The likeness of the curves of the rolling resistance index with the lower air pressure and the curves with the higher onerous force shows that lower pressure brings the same effect as higher load.

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