

# The determination of the rolling resistance coefficient of a passenger vehicle with the use of roller test bench method

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**Abstract.** Contemporary vehicle are designer to be eco-friendly. One of the factors limiting the energy consumption of driving processes is a low value of the rolling resistance coefficient. The rolling resistance depends on the construction features of a tire, exploitation conditions and the type of surface the car moves on. This article presents the results of experimental research of determining the rolling resistance coefficient with the use of laboratory method of roller test bench. The results presented here are a part of a wider research of determining the rolling resistance coefficient and the influence of research method on its value.

**Keywords:** rolling resistance coefficient, car transport, research methodology, roll test, car tires

## 1 Introduction

Nowadays cars are used as means of transport to carry people, animals and goods. In 2003 the estimated number of cars around the world was about 700 million. In 2020 this number is predicted to reach 1.2 billion. Worldwide car production in 2003 was 42 million cars a year whereas trucks 18.6 million. [1]. Vehicle designers aim the cars to be more and more ecological [2-4]. In order to lower energy consumption in vehicles the following solutions are used [1]:

- downsizing – lowering combustion engines capacity [5].
- increasing the efficiency of combustion engines,
- unconventional drives,
- lower the weight of the vehicle,
- reducing the aerodynamic resistance of the vehicle,
- reducing the rolling resistance [6, 7].

Wheel rolling resistance depends on tire construction features such as: tire width and height, tire offset diameter, kind of tread, speed index, number of cords plies, kind of fabrics in carcass and belt plies, rubber mixture of the tread and its hardness, rim width and the material it's made of [1]. Another factor influencing the rolling resistance is the kind of

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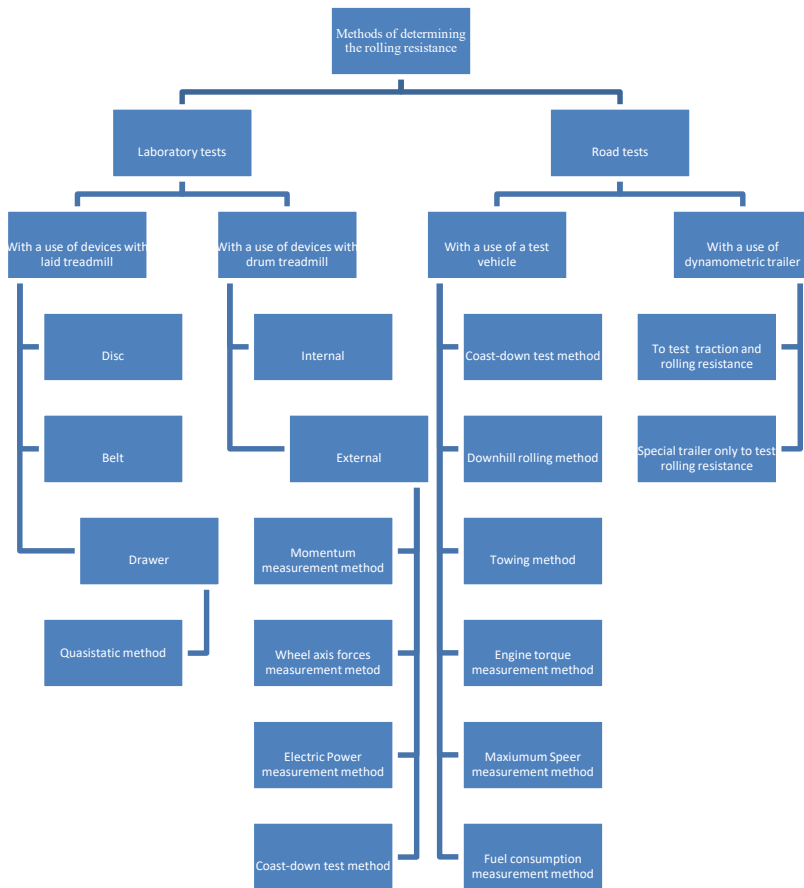
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surface, its state as well as micro and makrotexture [8-16]. The rolling resistance is also influenced by movement conditions, speed, wheel load, tire pressure, air temperature, rolling direction and tire tread wear [1, 8-15, 17-21].

The main reason for the occurrence of the rolling resistance is viscoelasticity properties of rubber objects [22]. Owing to this property, when tires are deformed they cause the energy dissipates as heat. While movement there is a displacement of forces causing the occurrence of momentum that resists the turning of the vehicle wheel. The value of this force is energy loss caused by tire deformation at a contact point with a hard surface This force is called the rolling resistance force [22]. The rolling resistance of a rubbered wheel is defined by a value of the rolling resistance force or the value of the rolling resistance coefficient. This article presents the results of experimental research of determining the rolling resistance coefficient with the use of laboratory method of roller test bench.

## 2 Research methods

There are two research methods of determining the rolling resistance coefficient : the laboratory methods and road tests. The division of methods is presented in Figure 1.



**Fig. 1.** Laboratory methods and road tests for determining the rolling resistance coefficient [1]

The values of the rolling resistance coefficient for passenger vehicles and trucks depending on the kind of surface they move at are presented in Table 1.

**Table 1.** The rolling resistance coefficients sheet [12]

Kind of the surface and bed	Passenger vehicles	Trucks
Smooth asphalt-concrete	0.012	0.010
Smooth concrete	0.014	0.012
Rough concrete	0.015	0.013
Granite blocks in a very good state	0.016	0.014
Granite blocks in a poor state	0.025	0.023
Stone blocks in a poor state	0.033	0.030
Road cobbled with field stones	0.040	0.035
Ground road in an avarege state	0.050-0.140	
Ground road sandy and moisty	0.080-0.150	
Dry sand	0.150-0.300	
Grass-covered area	0.060-0.110	
Snow	0.040-0.150	

## 2.1 Research object

In order to carry out the test the passenger car BMW series 3 E90 model 320d was used. It's a sedan powered by turbocharged Diesel engine of the capacity of 1995 cm<sup>3</sup> and 163 hp. The car was produced in 2005 and has rear axis drive. The car was equipped with aluminum rims and tires with the following parameters, Table 2.

**Table 2.** Parameters of aluminium rims and tires

Rim model	BMW Styling 268
Rim diameter	16"
Rim width	7"
Rim offset/ ET	31
Rim nuts spacing	5 × 120 mm
Tire manufacturer	BRIDGESTONE
Tire model	Turanza 001
Tire profile	205
Tire width	55
Tire diameter	16"
Tire load index	91
Tire Speer index	V
Date of production	35th week of 2015

## 2.2 Test equipment

The research was carried out at regional vehicle test station at Poznan University of Technology. The measurement was made with the use of machine produced by MAHA company Maschinenbau Haldenwang integrated with drive rollers.

### 3 The research methodology of rolling resistance in road conditions

Before the measurements were made tire pressure had been checked. Next the car was placed on a research stand which is roller test bench. Each test was performed separately for front and rear axis. During the test the rolling resistance force for each wheel was determined as well as braking force. The research for stationary method is presented in Figure 2.



Fig. 2. Research on rolling resistance for front and rear axis of the vehicle

### 4 Research results

The measurement results of rolling resistance force of front and rear axis of a vehicle recorded during the research are presented in figures 3 and 4.



Fig. 3. Screenshot of measurement system for the rolling resistance coefficient of front axis

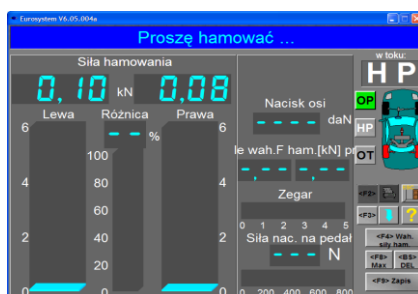


Fig. 4. Screenshot of measurement system for the rolling resistance coefficient of rear axis

During the research on rolling resistance on roller test bench the following values of rolling resistance force for each wheel were obtained. The results are presented in Table 3.

**Table 3.** The value of rolling resistance force for wheels of a tested vehicle

Front left wheel	0.09 kN
Front right Wheel	0.09 kN
Rear left Wheel	0.10 kN
Rear right Wheel	0.08 kN

In order to determine the rolling resistance coefficient using the stationary method it is necessary to know the mass distribution of the tested car. The scales were used and car was weight first entering the scales with front axis and then rear axis. The result for each axis was then divided by 2 in order to obtain the load for each of the vehicle wheels. The results are presented in Table 4.

**Table 4.** Wheel load of the tested vehicle

Front left wheel	427.5 kg
Front right Wheel	427.5 kg
Rear left Wheel	399 kg
Rear right Wheel	399 kg

Using the equation for rolling resistance [17]:

$$F = m \cdot g \cdot f_t, \tag{1}$$

where:

$F$  – rolling resistance force [N],

$m$  – vehicle mass [kg],

$g$  – standard gravity [m/s<sup>2</sup>],

$f_t$  – rolling resistance coefficient.

After transformation we receive:

$$f_t = \frac{F}{m \cdot g}. \tag{2}$$

The values of rolling resistance coefficient were determined for each of the wheels, for example:

$$f_t = \frac{90}{427.5 \cdot 9.81} = 0.02146. \tag{3}$$

The results of obtained values of rolling resistance coefficient calculated for stationary method on roller test bench. The obtained values of rolling resistance coefficient are presented in Table 5.

**Table 5.** The values of rolling resistance coefficient determined for stationary method on roller test bench

Front left wheel	0.02146
Front right Wheel	0.02146
Rear left Wheel	0.02555
Rear right Wheel	0.02044
<b>Average value of the coefficient</b>	<b>0.02223</b>

## 5 Summary

During the research a passenger car was used. The rolling resistance coefficient was determined with the use of stationary method on roller test bench, during which also rolling resistance force was measured which is necessary to turn each of the vehicle wheels. In this method it is necessary to know the exact mass distribution of the tested vehicle which influences significantly the obtained value of the coefficient. For a passenger vehicle moving on an asphalt road the value of rolling resistance coefficient presented in literature sources equals 0.012.

The values of rolling resistance coefficient determined with the use of experimental research laboratory method vary from the ones in literature sources. The assumed method does not reflect the proper range of interaction of tire with surface. What is more, it can introduce into measurement system interference such as the rolling resistance of the rollers or drive systems. The range of resistance of measurement device is not fully examined which can influence the results. However, also literature sources miss information what method was used to determine the values of rolling resistance coefficient.

It is worth mentioning that lowering the value of rolling resistance coefficient even by a small percent positively influences the economical and ecological aspects of driving. The lower the value of rolling resistance coefficient is the lower fuel consumption is. With such a high number of cars around the world it means saving the natural resources and reducing the amount of exhaust fumes in the environment. It is the reason for a constant research on the reduction of energy consumption of the vehicles, which requires the unification of research methods and determining the ranges of their comparability.

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