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X International Conference SILESIAN ROAD FORUM

ELANORE – study on rolling resistance of car tires

ELANORE – badania nad oporem toczenia opon samochodowych

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GDAŃSK UNIVERSITY OF TECHNOLOGY

Project ELANORE

Improvement of the EU tire labelling system for noise and rolling resistance

Financing program:

NCBiR under Norwegian Financial Mechanism 2014-2021, POLNOR / 2019, *Energy, transport and climate*

Project start date: 2020.05.01 and finish date: 2023.04.30

Partners:

- **Gdansk University of Technology (GUT)**

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- **SINTEF AS, by its institute SINTEF Digital**

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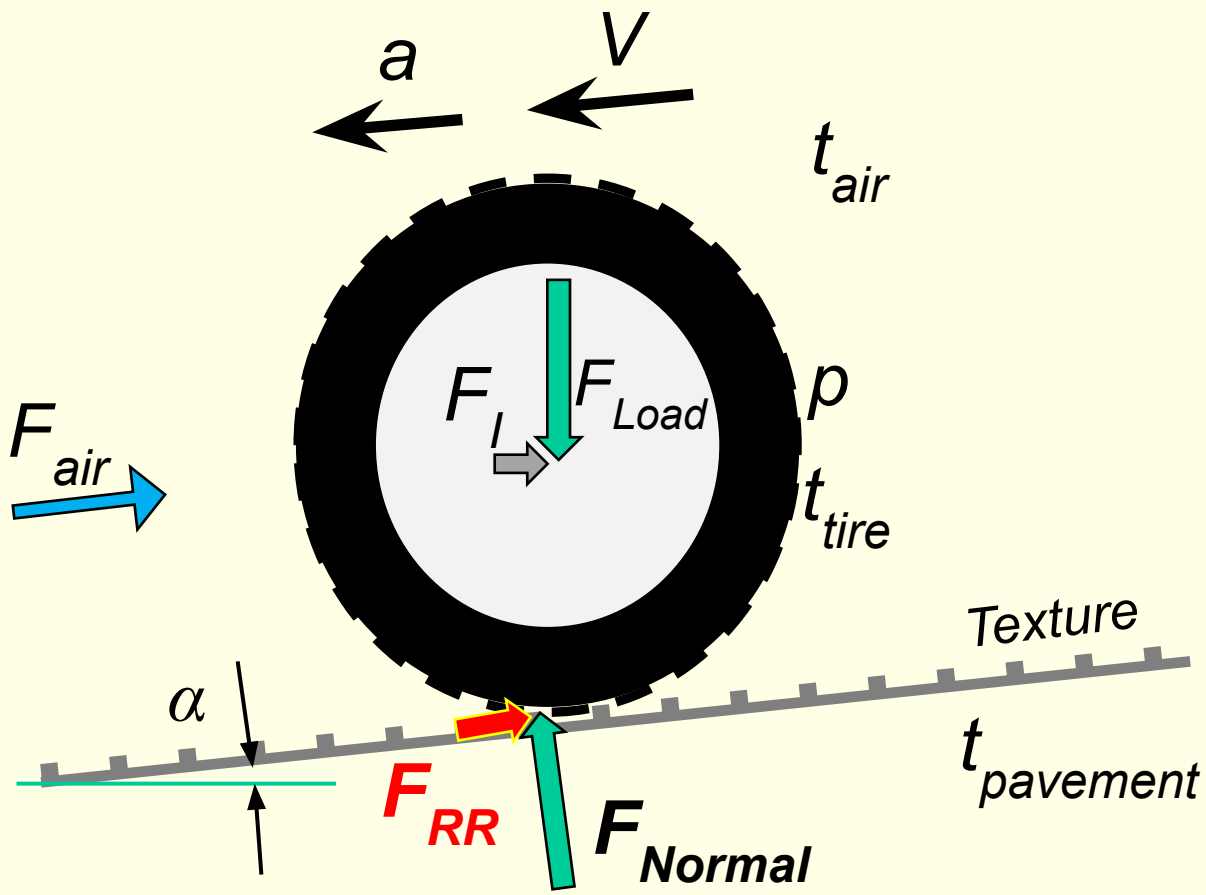
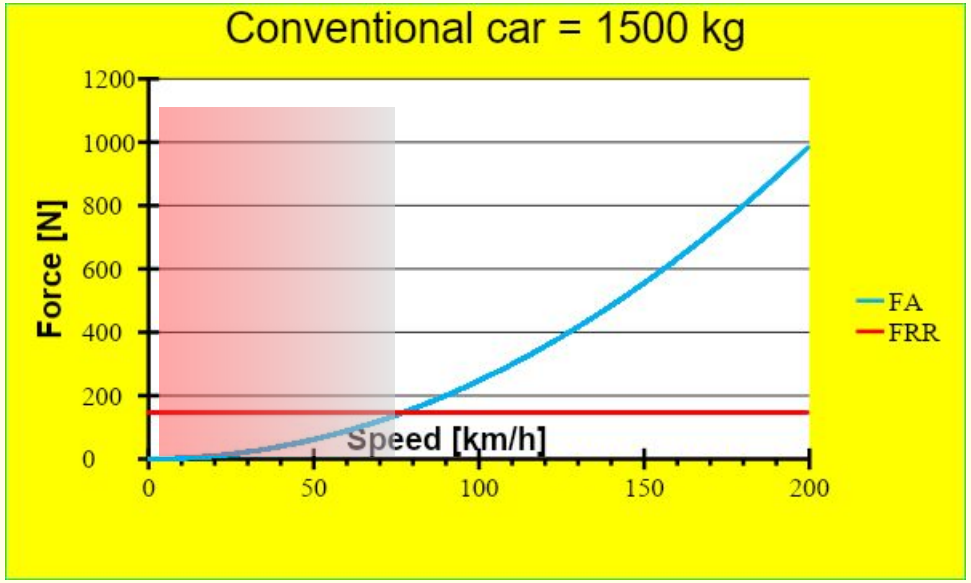
ROLLING RESISTANCE OF TIRES AND ROAD SURFACE



$$C_{RR} = \frac{F_{RR}}{F_{Normal}}$$

For modern tires C_{RR} = 0.006 do 0.015

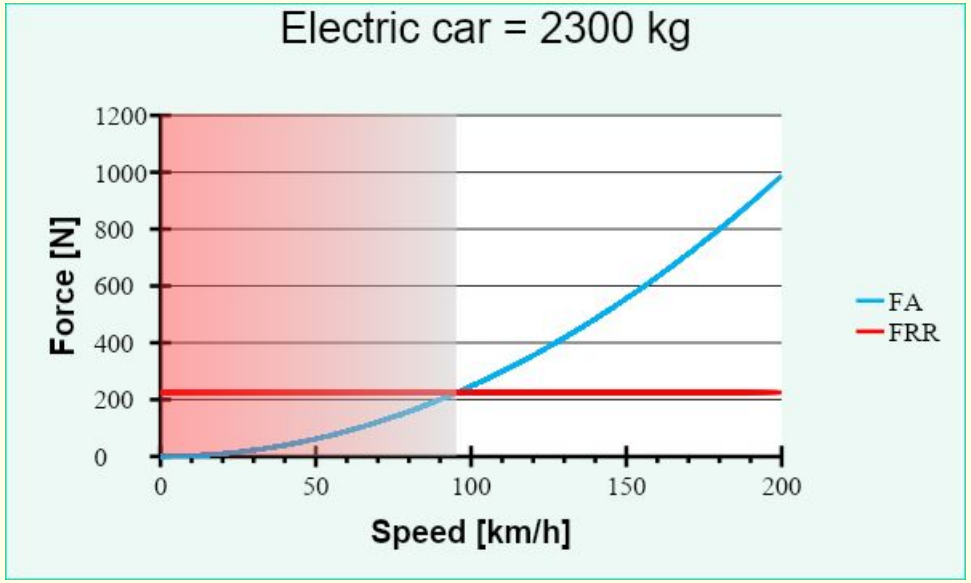
HOW IMPORTANT IS THE ROLLING RESISTANCE OF TIRES?



Cx = 0.25

F = 2 m^2

CRR = 0.01



FA – aerodynamic drag

FRR – rolling resistance force

Review of the rolling resistance measurement methods

Laboratory and road methods used for measuring the rolling resistance of tires on road surfaces.

Laboratory methods:

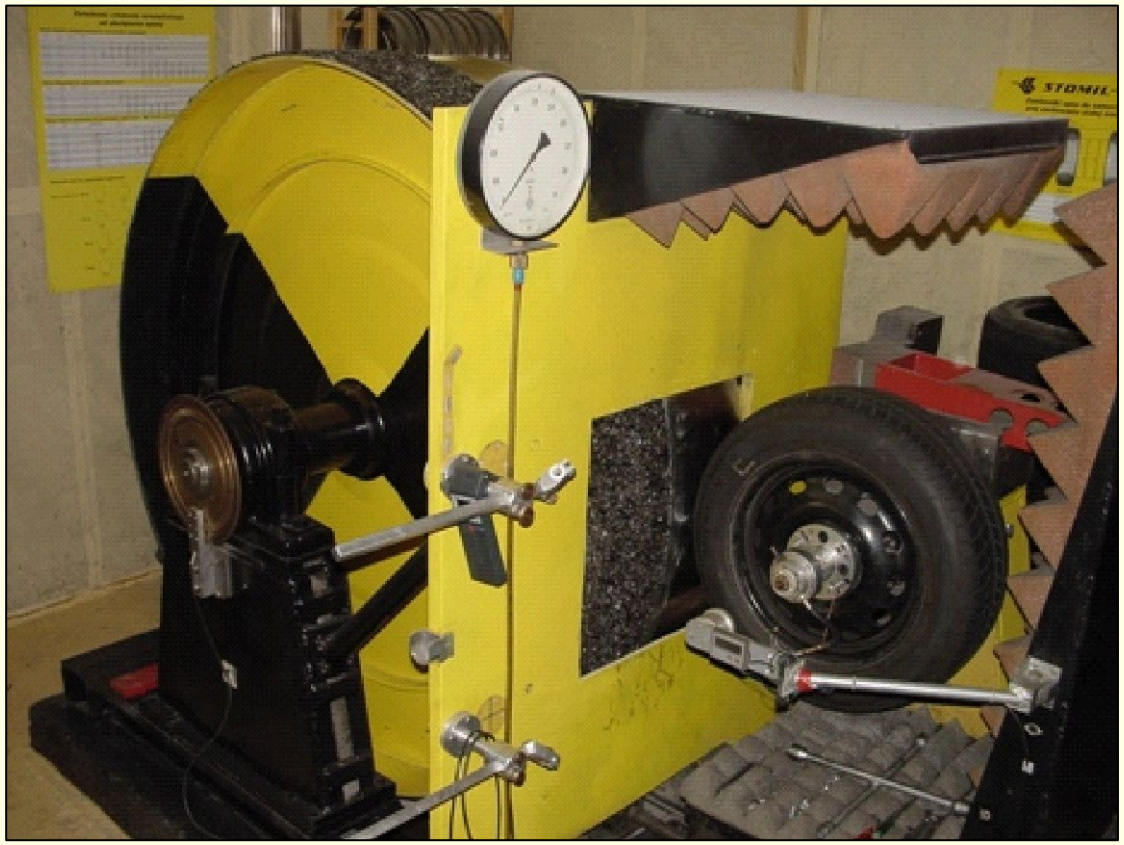
- force method at tire spindle;
- power method at drum axis;
- deceleration method;
- torque method at drum axis.

Road methods:

- coastdown method;
- method based on measuring energy or fuel consumption;
- trailer method.

Review of the rolling resistance measuring – laboratory methods

Torque method at drum axis (used at GUT)



Drum diameter 1.7m

$$F_r = \frac{T_t}{R} - F_{pl}$$

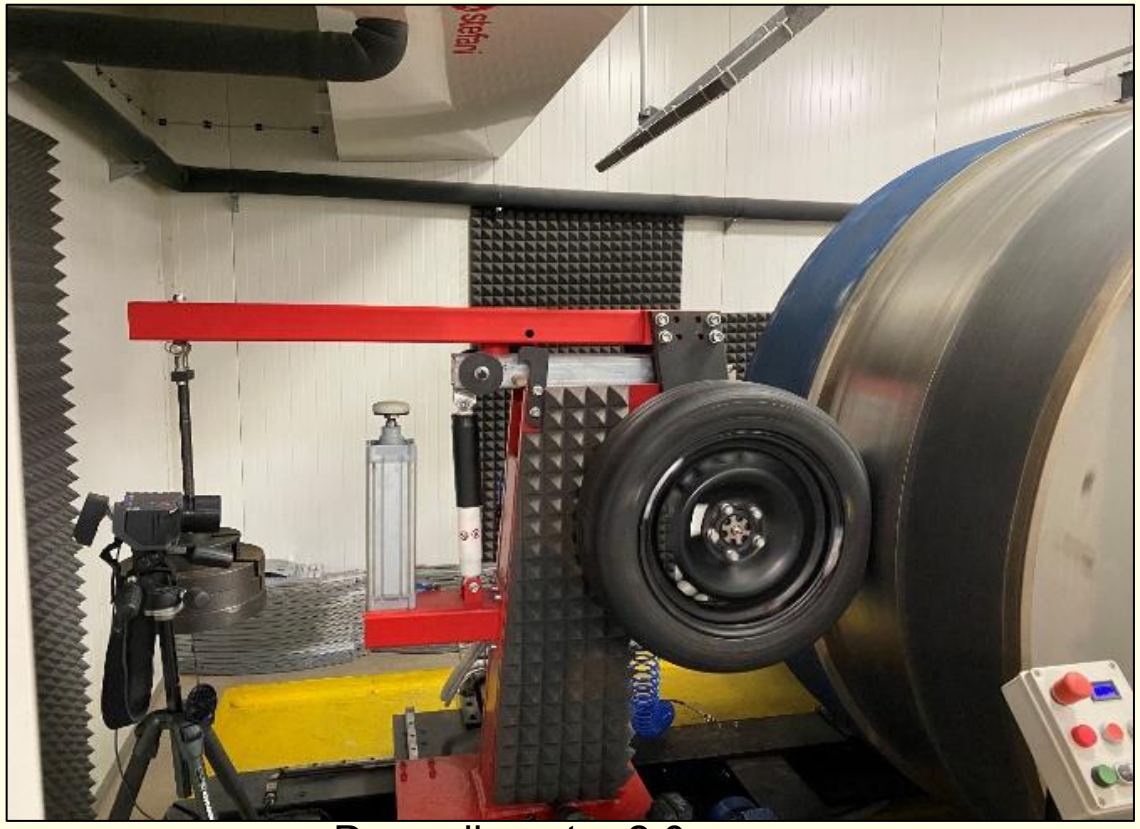
where:

- F_r is the rolling resistance force [N];
- T_t is the input torque [Nm];
- R is the test drum radius [m];
- F_{pl} is the parasitic losses.

Review of the rolling resistance measuring – laboratory methods

Torque-based method used at Gdansk University of Technology

In laboratory measurements parameters are stable and replicatable.



Drum diameter 2.0 m

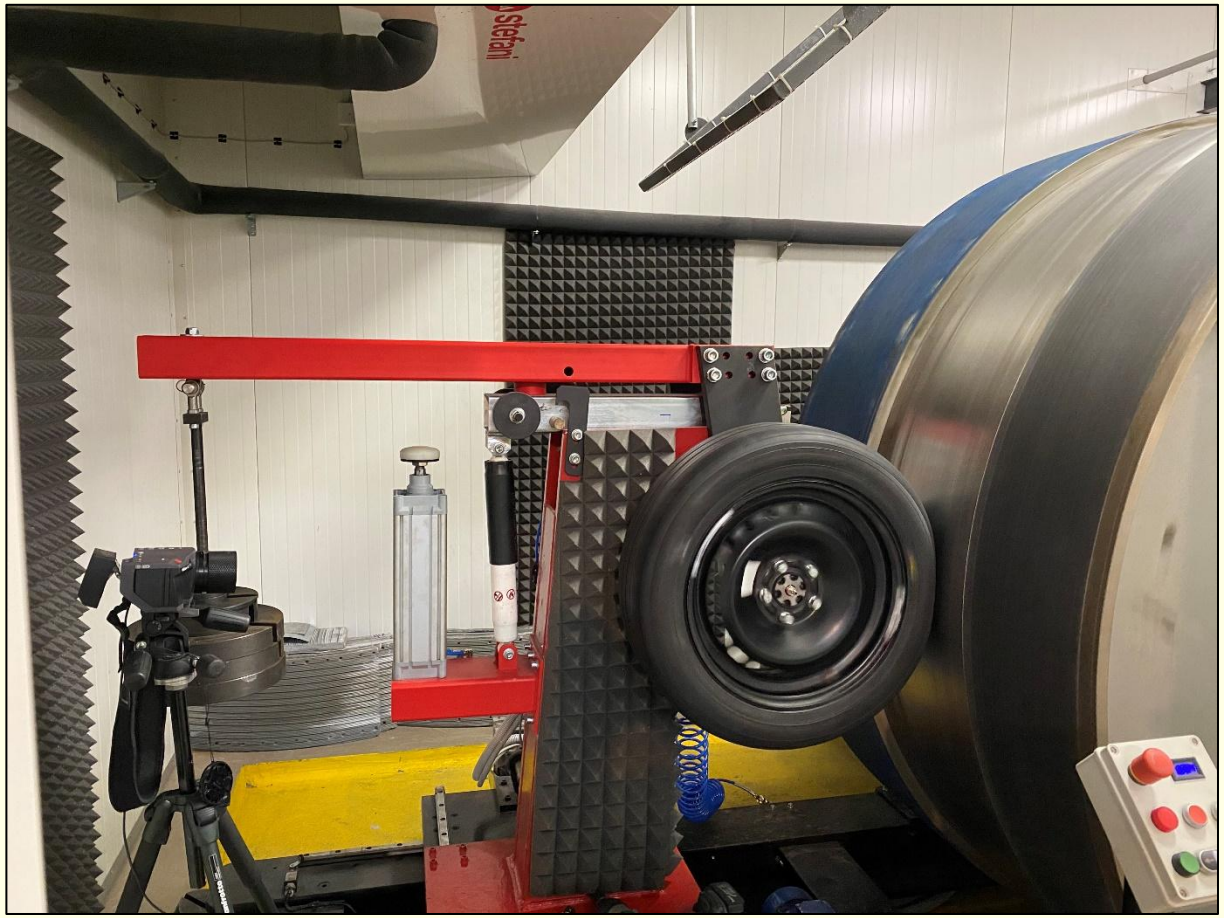
Significant parameters of rolling resistance force:

- speed;
- load;
- inflation pressure;
- air temperature;
- drift and wheel camber angle;
- energy loss in tires.

The above parameters directly influence the temperature of the tire's rubber massive.

Review of the rolling resistance measuring – laboratory methods

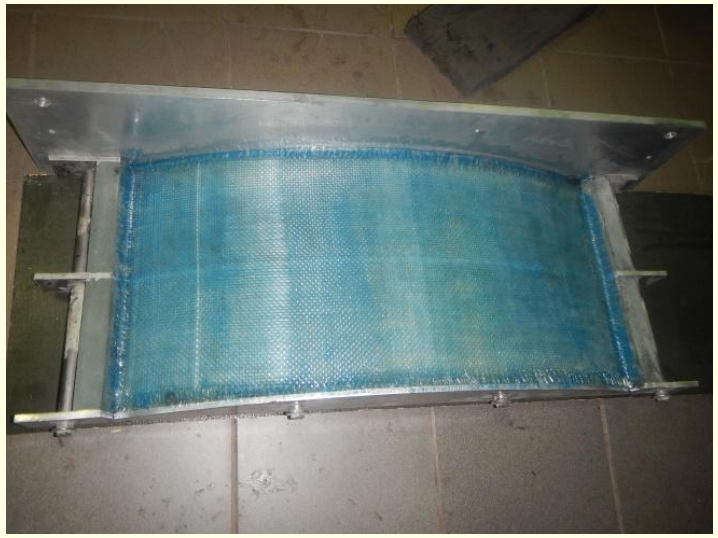
Torque-based method used at Gdansk University of Technology



Replica of DAC 16 mounted to the drum

A roadwheel facility built at the Gdańsk University of Technology. There are three test surfaces mounted to the drum. From the left: replica of SMA8, steel and Safety Walk M80

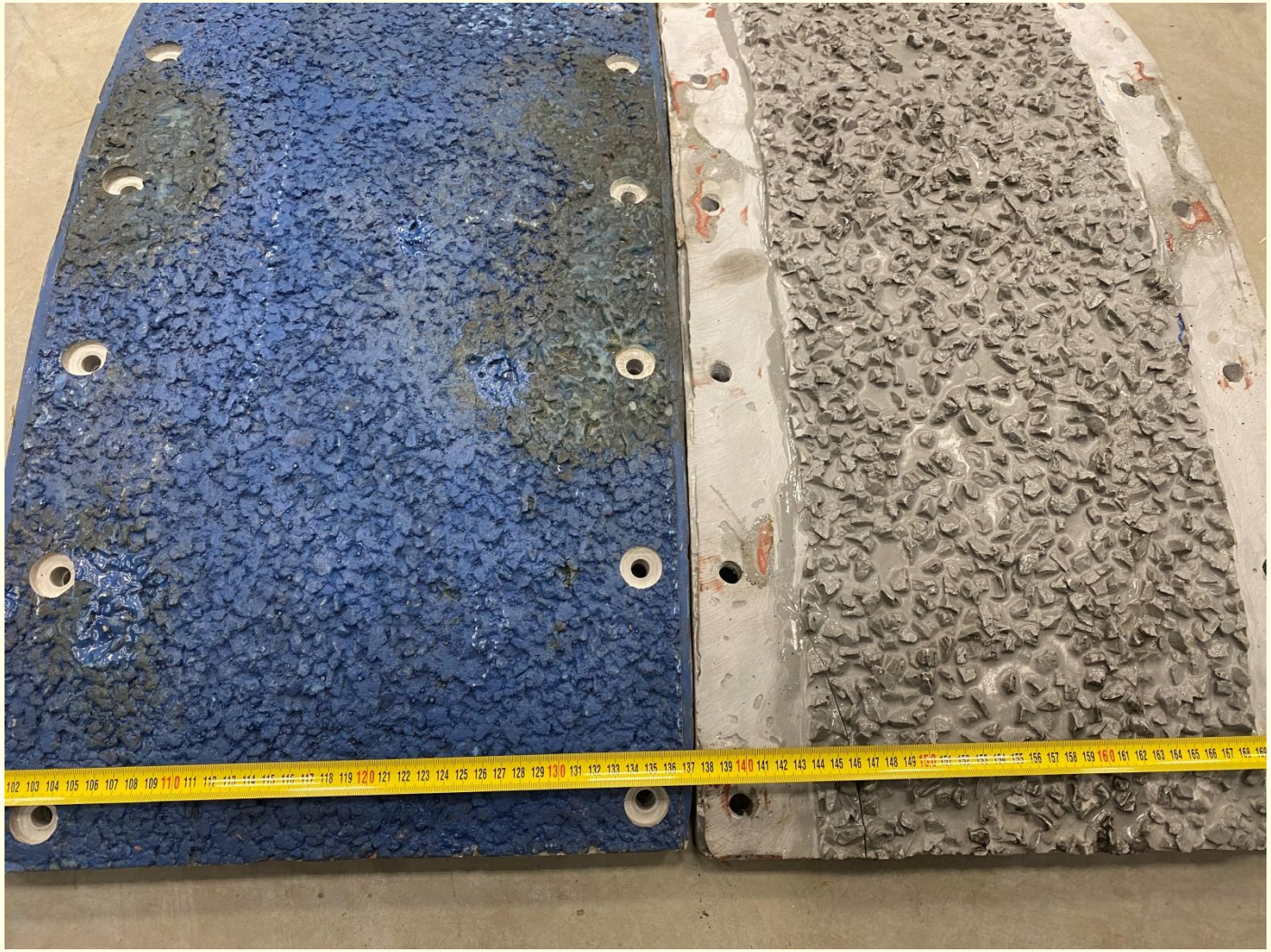
Method developed at the Gdańsk University of Technology.



Stages of producing a replica of a real road surface.

Review of the rolling resistance measuring – laboratory methods

Replicas of road surfaces

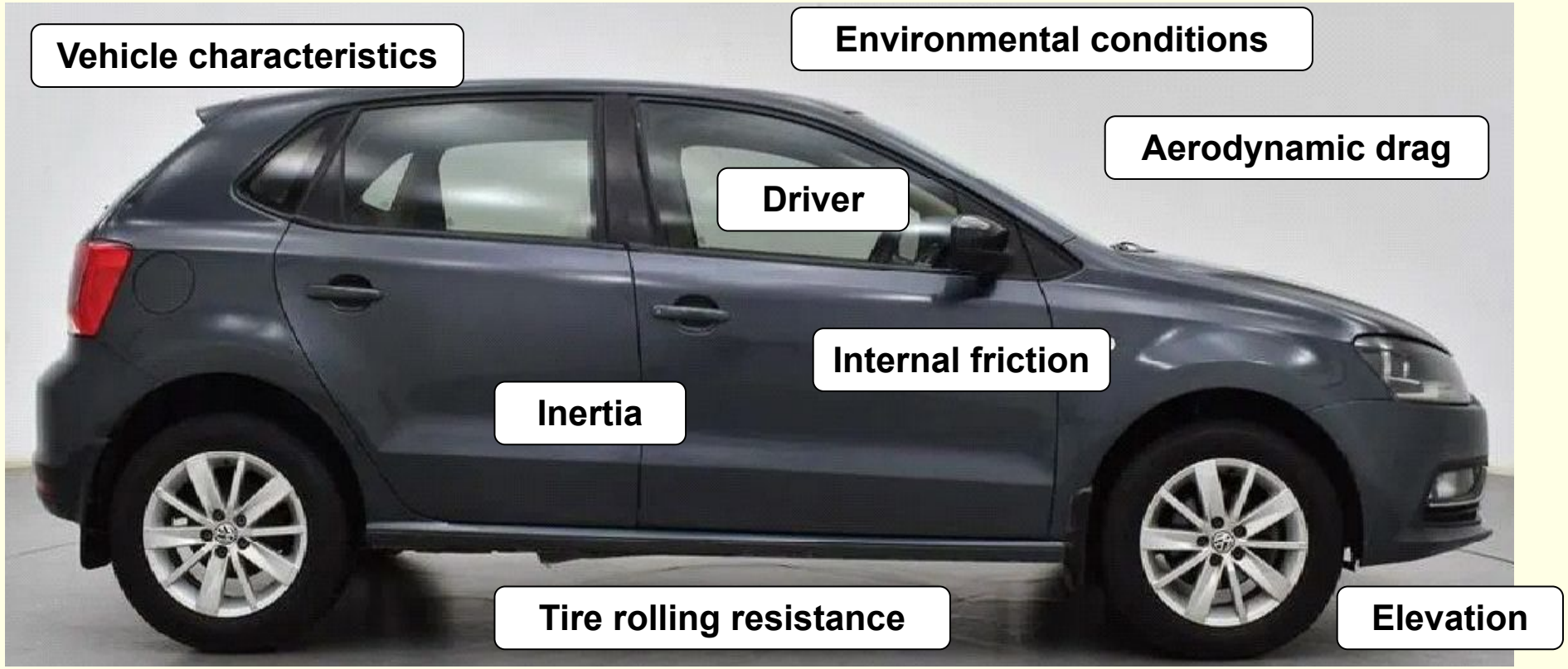


SMA8 Surface dressing APS4

Replica developed as part of the ELANORE project

Review of the rolling resistance measuring – road methods

1. Method based on measuring energy or fuel consumption.
2. Coastdown method



Review of the rolling resistance measuring – road methods

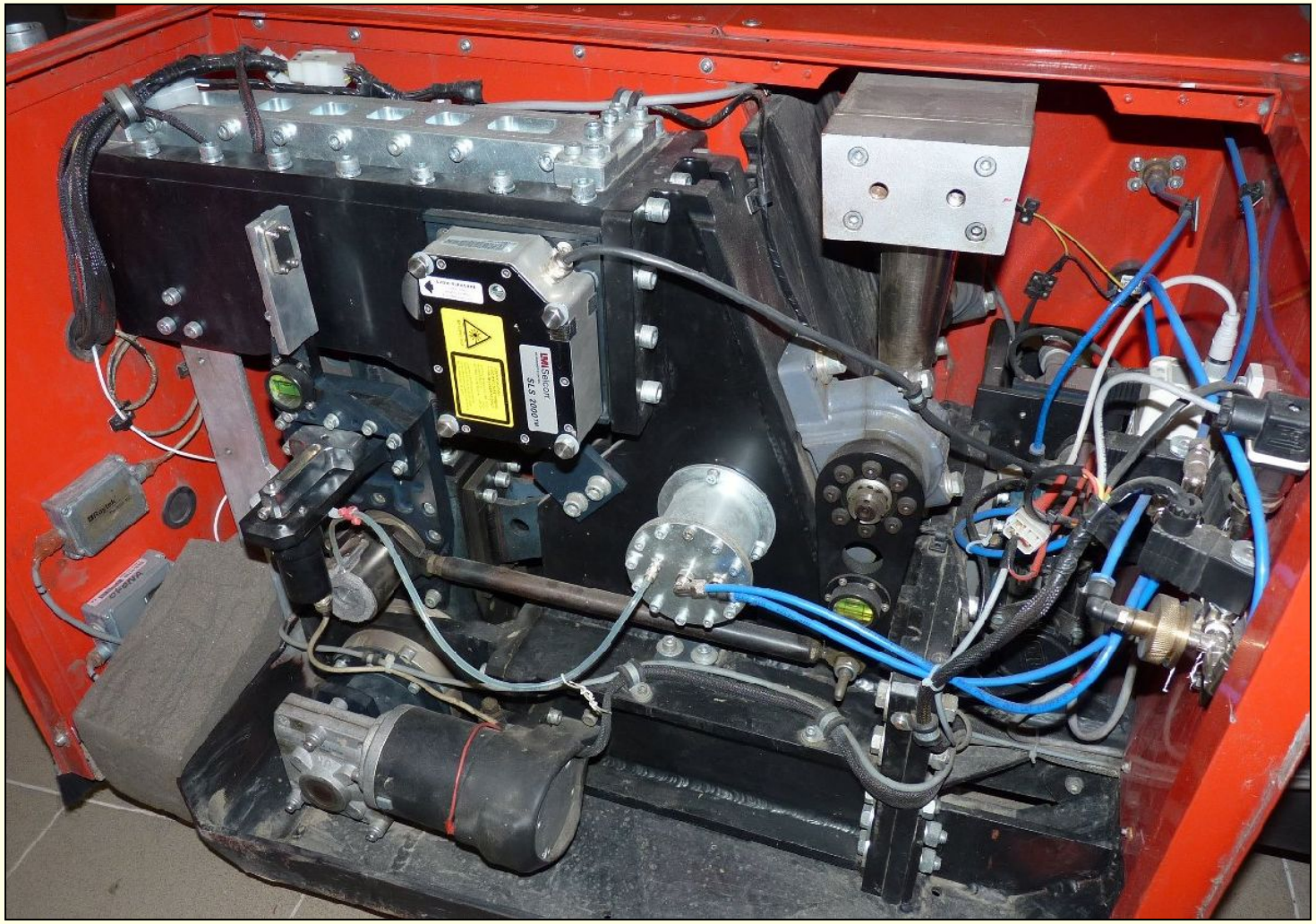
Trailer method

R^2Mk.2 trailer is used to measure tire/road rolling resistance.

Tire diameter varies from 570 to 730 mm and width up to 245 mm.

Review of the rolling resistance measuring – road methods

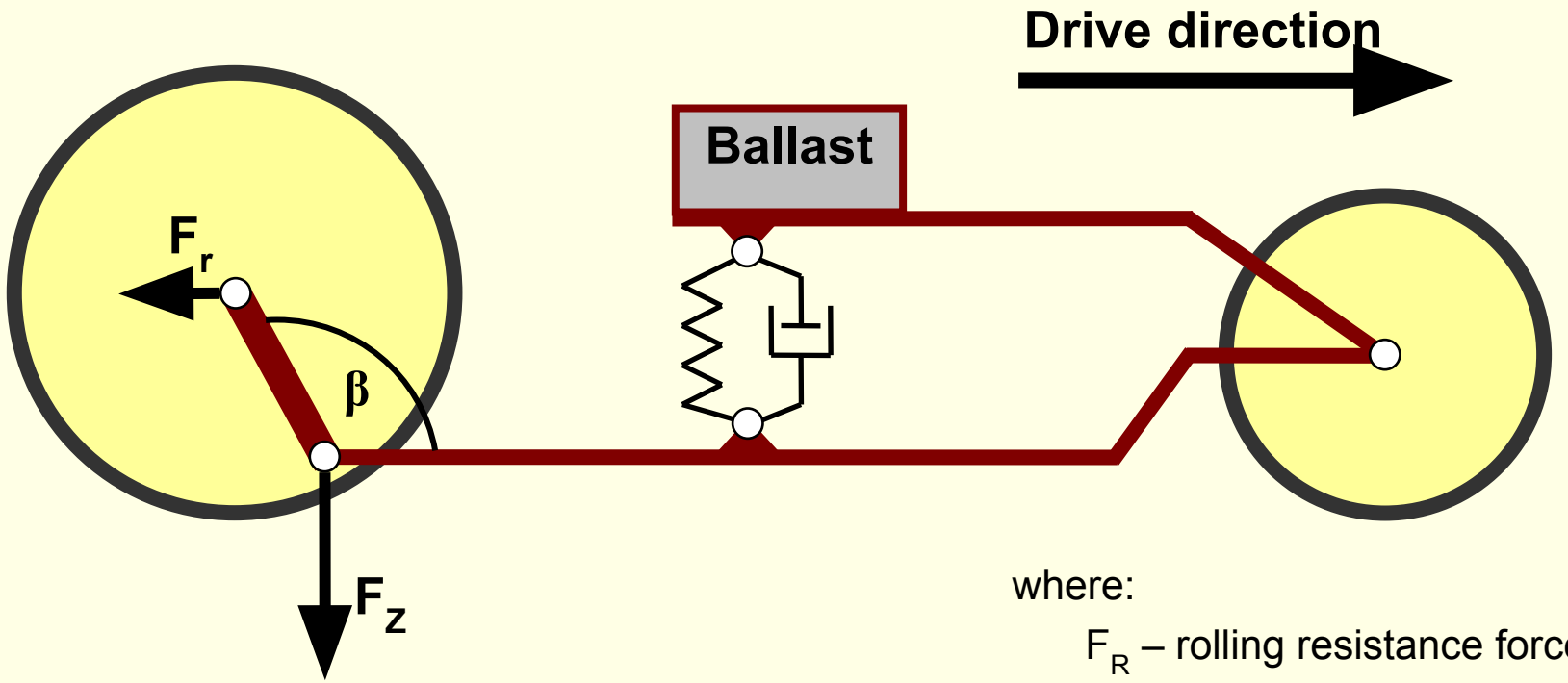
Trailer method



R^2Mk.2 trailer measurement system.

Review of the rolling resistance measuring – road methods

Trailer method



where:

F_R – rolling resistance force

F_z – normal force

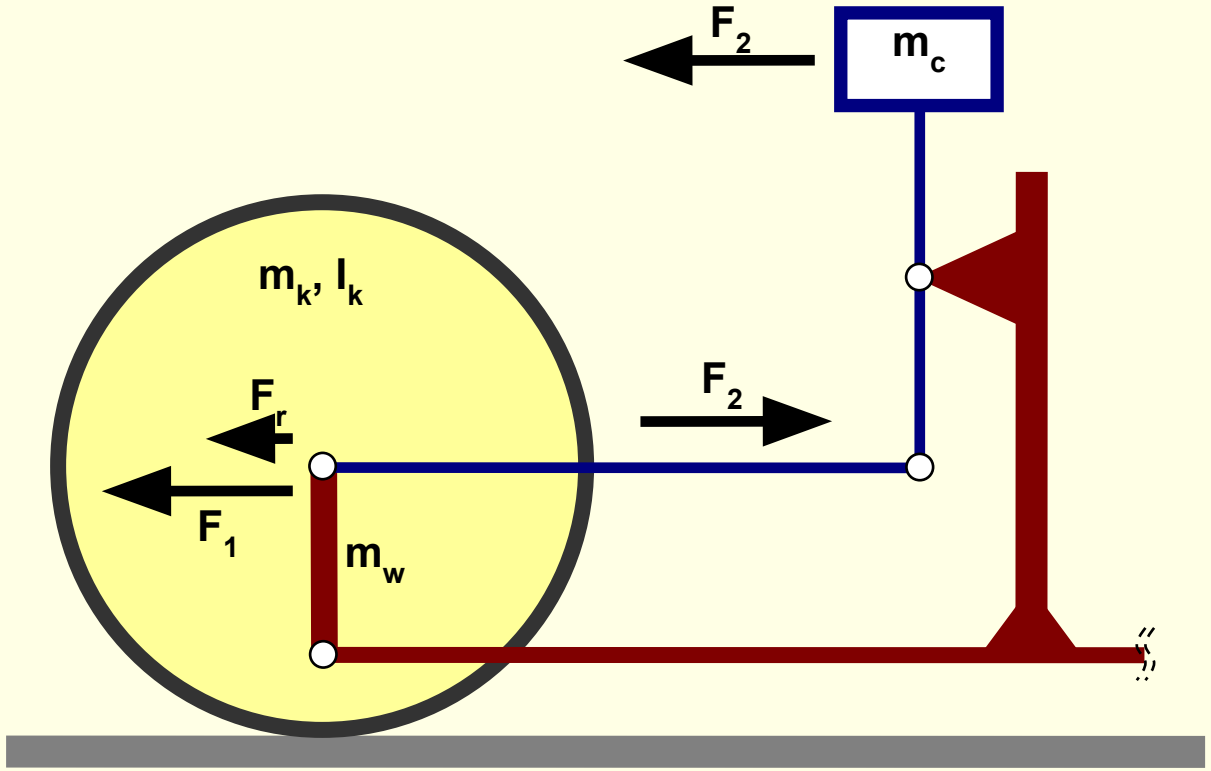
β –testing arm angle

R^2Mk.2 trailer scheme.

Angle β is equivalent to rolling resistence force F_r.

Review of the rolling resistance measuring – road methods

Trailer method



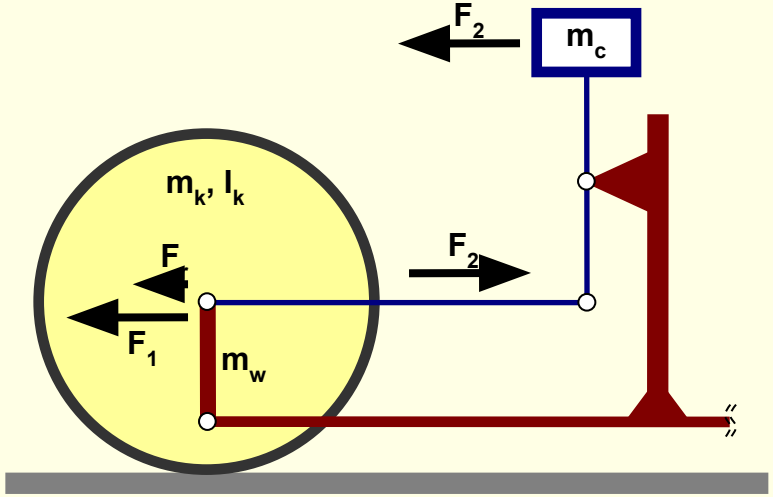
where:

- F_r - rolling resistance force
- F_1 - the force resulting from acceleration and the elevation of the road
- F_2 - force balancing F_1 force
- m_c - counterweight mass
- m_w - arm mass
- m_k - wheel mass
- I_k - wheel inertia

R^2Mk.2 trailer measurement system scheme.

Review of the rolling resistance measuring – road methods

Trailer method



R²Mk.2 trailer measurement system scheme.

$$F_1 = F_{1b} + F_{1w}$$

where:

F_{1b} – component of F_1 force resulting from inertia of measuring arm and tested wheel in progressive and rotational movement,

F_{1w} – component of F_1 force resulting from the mass of measuring arm and tested wheel during uphill

$$F_{1b} = \left(m_k + m_w + \frac{I_k}{r_k^2} \right) \cdot a$$

$$F_{1w} = \left(m_k + m_w \right) \cdot g \cdot \sin \alpha$$

where:

m_k – tested wheel mass,

m_w – tested arm mass,

I_k – tested wheel inertia,

r_k – tested wheel radius,

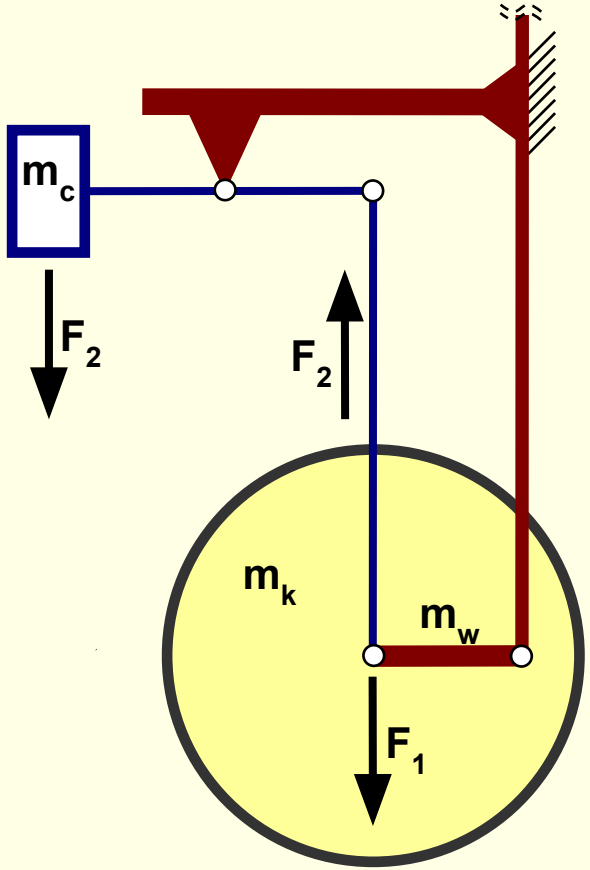
a – trailer linear acceleration,

g – gravity,

α – elevation angle.

Review of the rolling resistance measuring – road methods

Trailer method



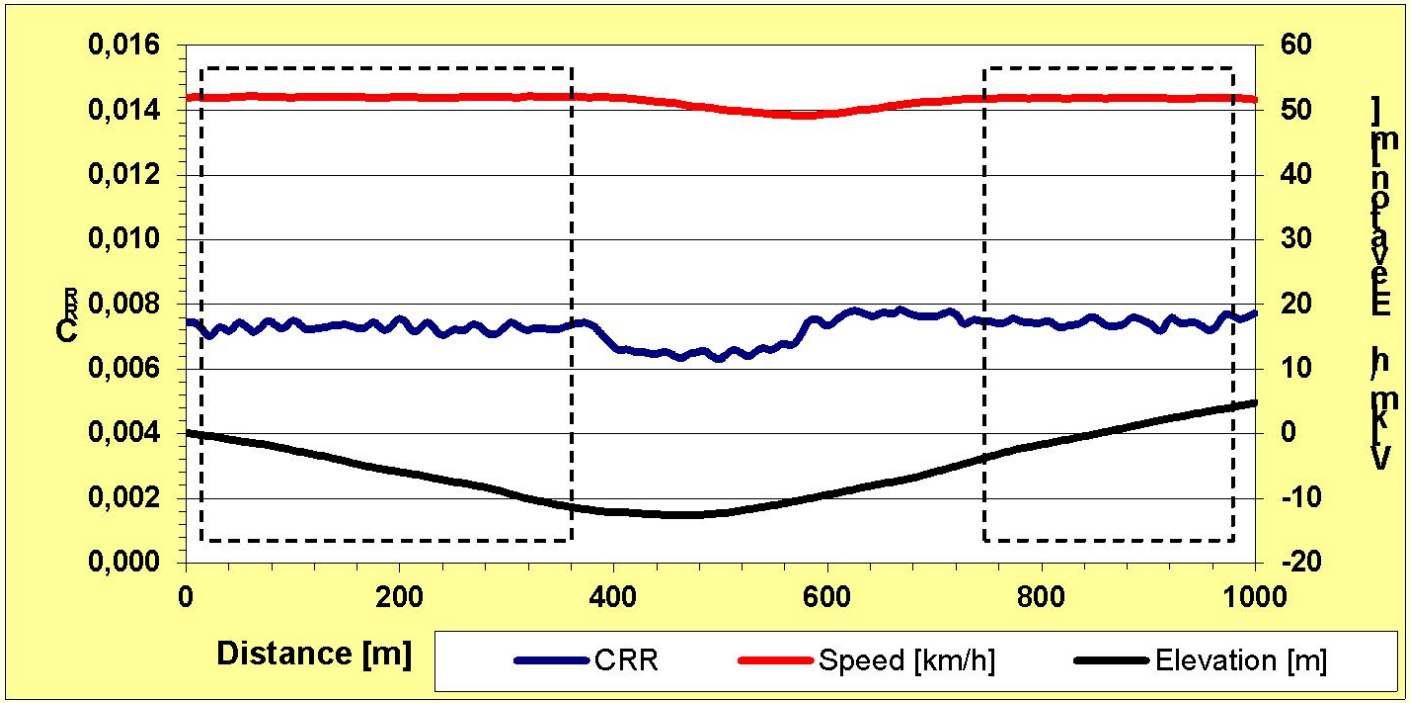
The mass m_c should be chosen to get equality:

$$F_1 = F_2$$

Method of static balancing of the measuring system of the R2 Mk.2 trailer

Review of the rolling resistance measuring – road methods

Trailer method



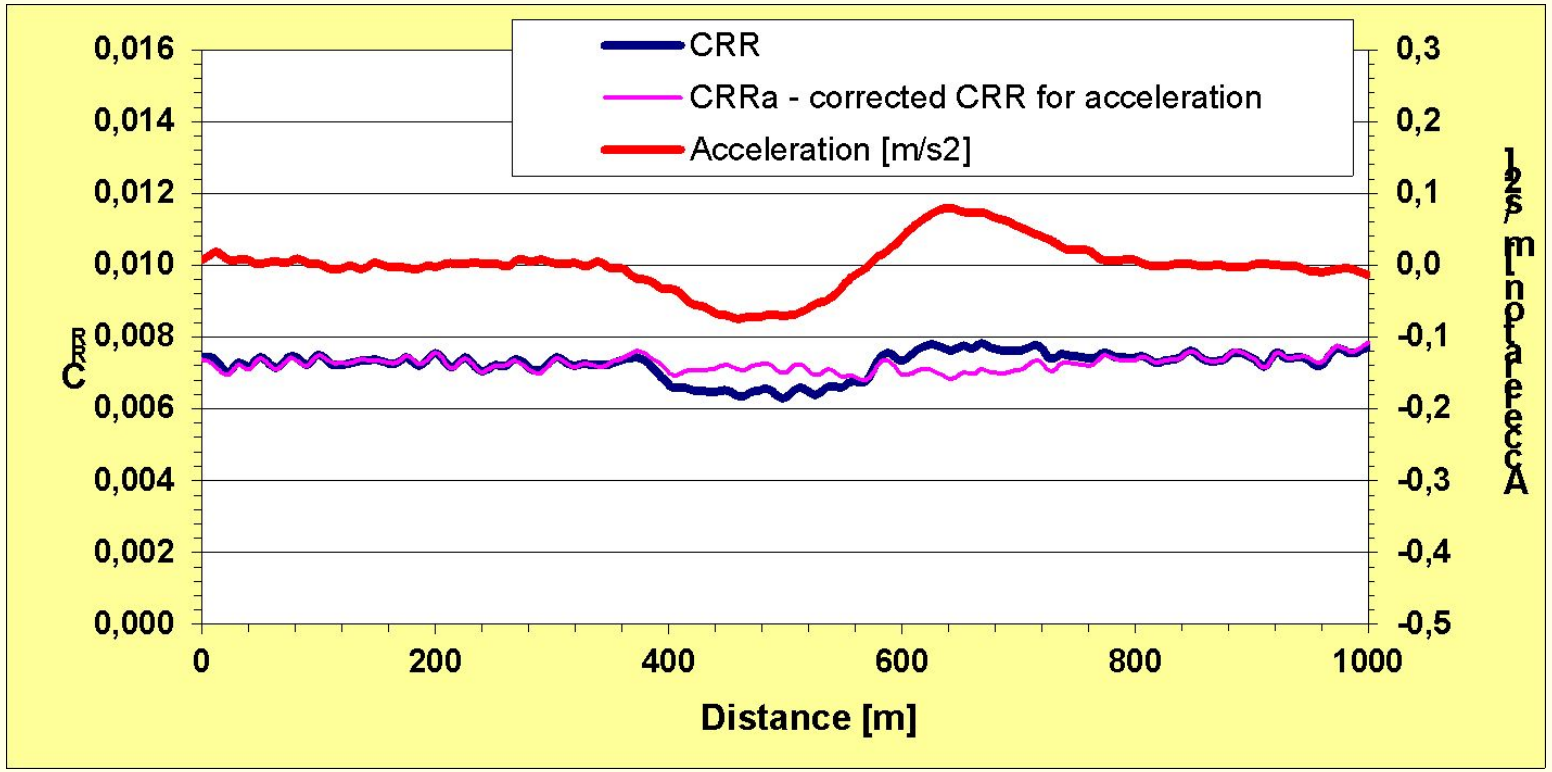
Sample results received in road conditions.

The test was carried out in the tunnel under the ’Martwa Wisła’ river in Gdańsk. The inclination of the tunnel at the entry and at exit parts is approximately 3%.

- Surface: SMA8,;
- speed: 50 km/h;
- test tire: SRTT (Uniroyal Tiger Paw M+S P225/60R16 97S).

Review of the rolling resistance measuring – road methods

Trailer method



Sample results received in road conditions.

An example of rolling resistance correction based on the longitudinal acceleration of the R2 Mk.2 trailer according to the equation:

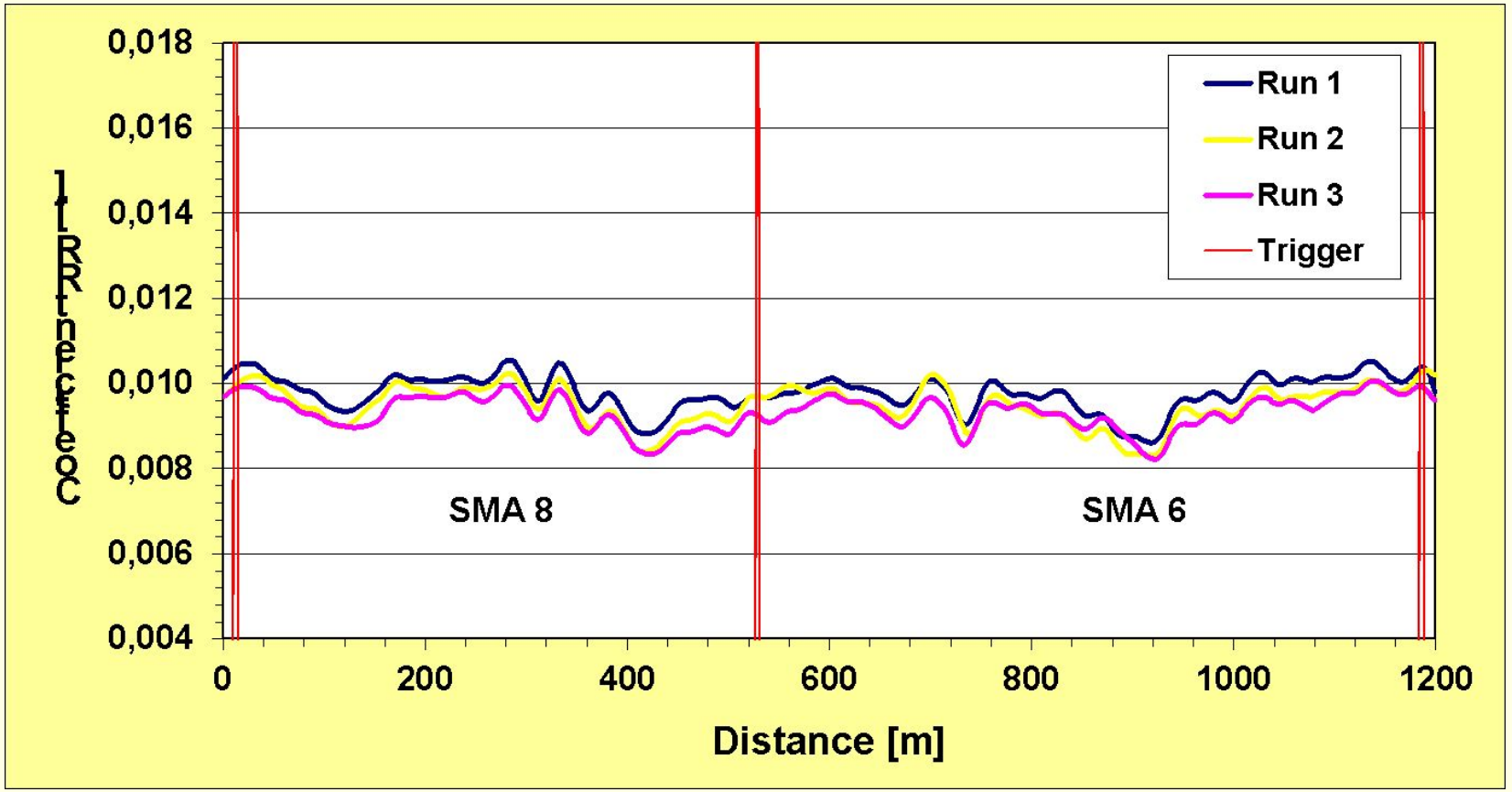
$$C_{RRa} = C_{RR} - c_a \cdot a$$

where:

c_a = 0,01 for tire SRTT

Review of the rolling resistance measuring – road methods

Trailer method



Sample results of measuring the rolling resistance coefficient received using the R2Mk.2 trailer.

Test tire: SRTT – UNIROYAL Tiger Paw, P225/60R16 97S M+S.

Conditions:

- speed: 80 km/h;
- inflation pressure: 210 kPa;
- load: 4150 N;
- air temperature: 20,2 deg C;
- surface temperature: 32,9 deg C;
- tire sidewall temperature: 36,3 deg C.

Review of the rolling resistance measuring – road methods

Trailer method

On the road we can control:

- speed;
- load;
- inflation pressure.

Measurements in road conditions are much more difficult.

We cannot control air and road surface temperatures.

We have no influence on the humidity of the surface.

The above parameters and energy loss in the tire, directly influence the tire's rubber temperature.

The temperature of the tire's rubber directly affects the pressure inside the tire.

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Thank you for your attention

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