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ABOUT THE ROLLING RESISTANCE (RR) TRAILER AND PARAMETERS INFLUENCING RR

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Overview

1. Introduction
2. Trailer measurements
3. Coast down measurements
4. One-third-octave band texture levels
5. Conclusions

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1. Introduction

Rolling resistance (RR) ↑
Energy consumption ↑
CO_2 emission ↑

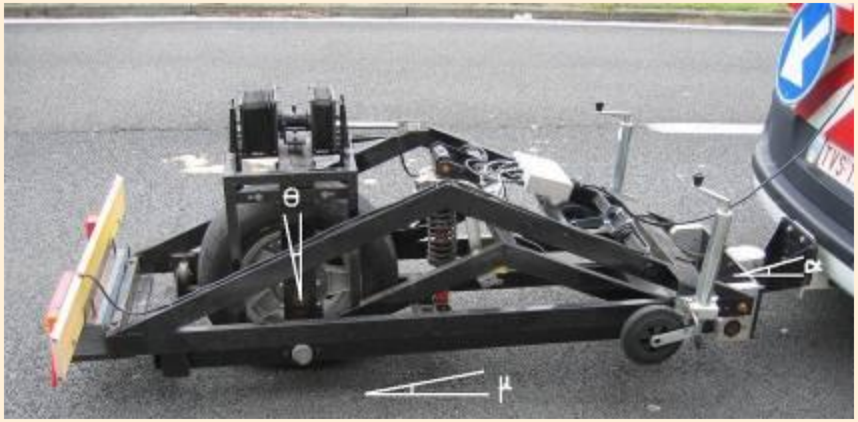
Influence of road surface?

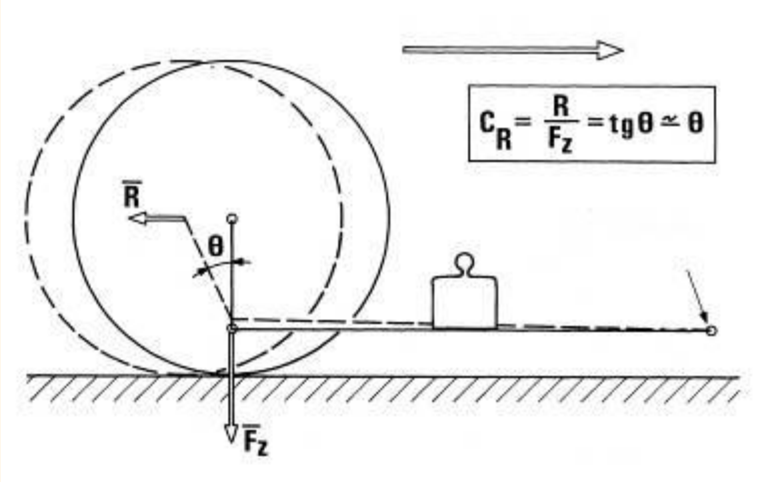
Rolling Resistance Coefficient:
dimensionless ratio of RR force to wheel load
$C_r = F_r / F_z$
where the forces F_r and F_z are magnitudes and not vectors

1. Introduction

Trailer measurements

- **Quarter-car with car suspension**
- **Tyre load 2000 N**
- **Force R counteracting rolling of wheel causes backward motion over angle θ**
- **Sensors:**
  - **Inclination θ wheel carrier - frame trailer**
  - **Inclination μ frame trailer - horizontal plane**
  - **Inclination α trailer - towing vehicle static condition**
  - **Tyre temperature: external infrared sensor at sidewall near shoulder tyre**
  - **Speed**
  - **Acceleration**





1. Introduction

Coast down measurements

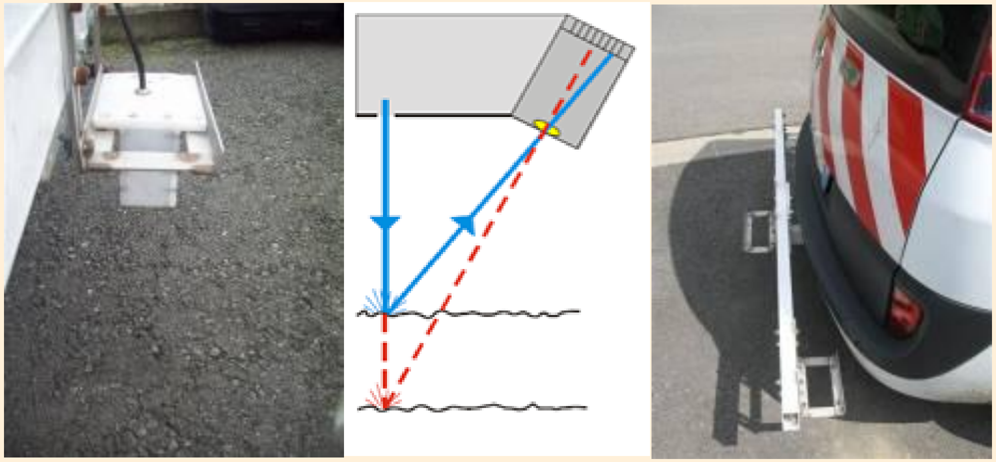
- Rudimentary measurements
- No specialized measuring equipment
- Each vehicle was coasted with transmission disengaged until standstill
- Distance travelled was measured
- A lot of parameters are still influencing the measurements: e.g. vehicle RR and aerodynamical resistance

1. Introduction

Texture measurements

Dynamic laser profilometer BRRC:

- 78 kHz sample frequency
- laser beam 0.2 mm diameter
- 40 km/h when measuring in steps of 0.2 mm
- vertical measuring range 64 mm
- 16-bit system
- vertical resolution 1 µm



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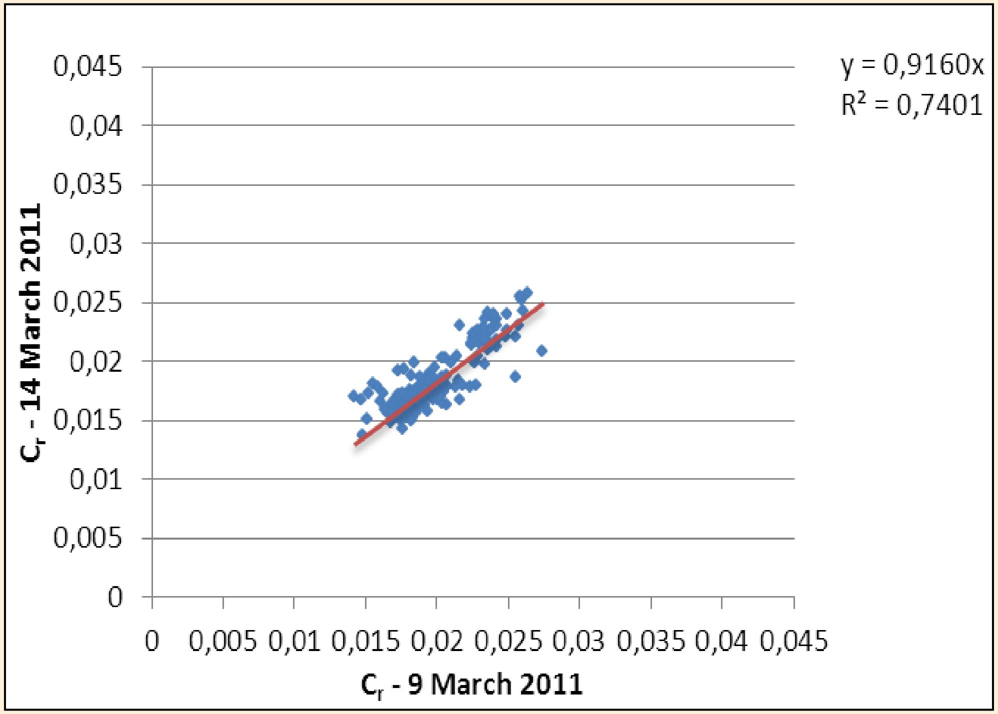
2. **Trailer measurements**
3. **Coast down measurements**
4. **One-third-octave band texture levels**
5. **Conclusions**

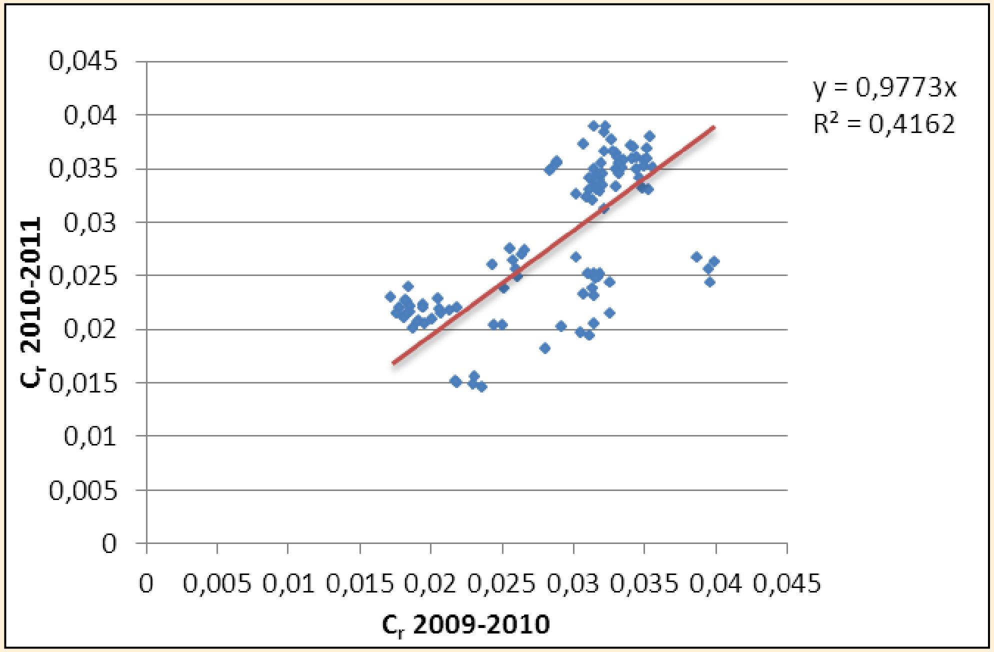
2. Trailer measurements

Short time repeatability

- 9 test tracks
- 5 days in between
- Temperature correction:
  $C_r(T) = C_r(T_0) * e^{((T_0 - T)/T_1)}$
  where $T_0 = 30$ °C, $T_1 = 50$ °C
  [Descornet]
- All outliers were included in graphs and analyses
- Good repeatability (slope approaches 1)
- Reasonable correlation



2. Trailer measurements



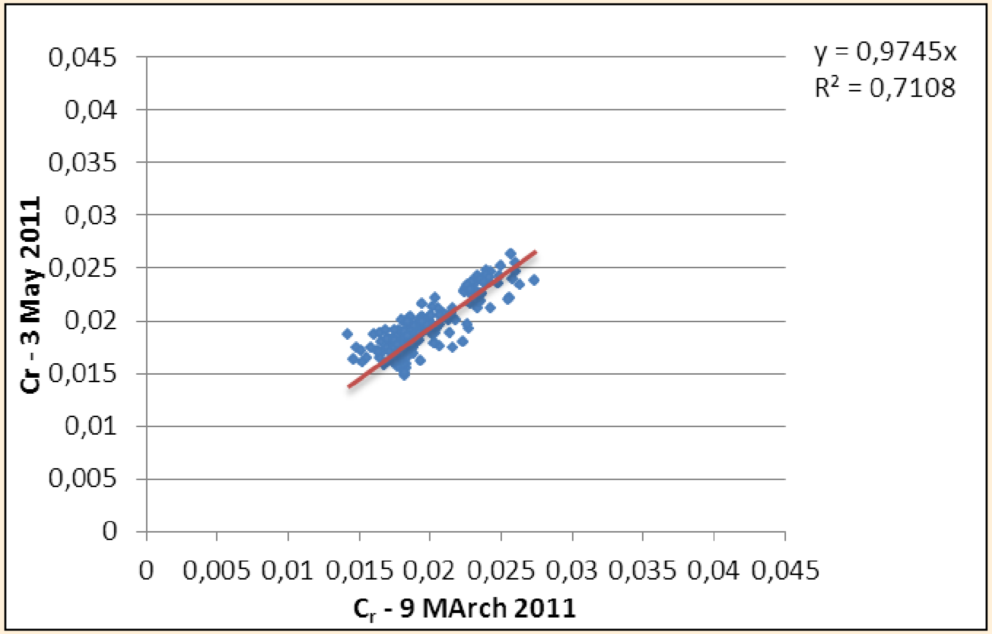
<u>Long time repeatability</u>

- **Part I:**
  - **2 measurement campaigns**
  - **10 test sections**
  - **2 different groups of researchers**
  - **8 – 11 months**
- **Good repeatability (slope approaches 1)**
- **Correlation not so good**
- **Possible reasons:**
  - **2 different groups of researchers, communication errors**
  - **Wear road surface**
  - **Calibration errors students**

2. Trailer measurements

Long time repeatability

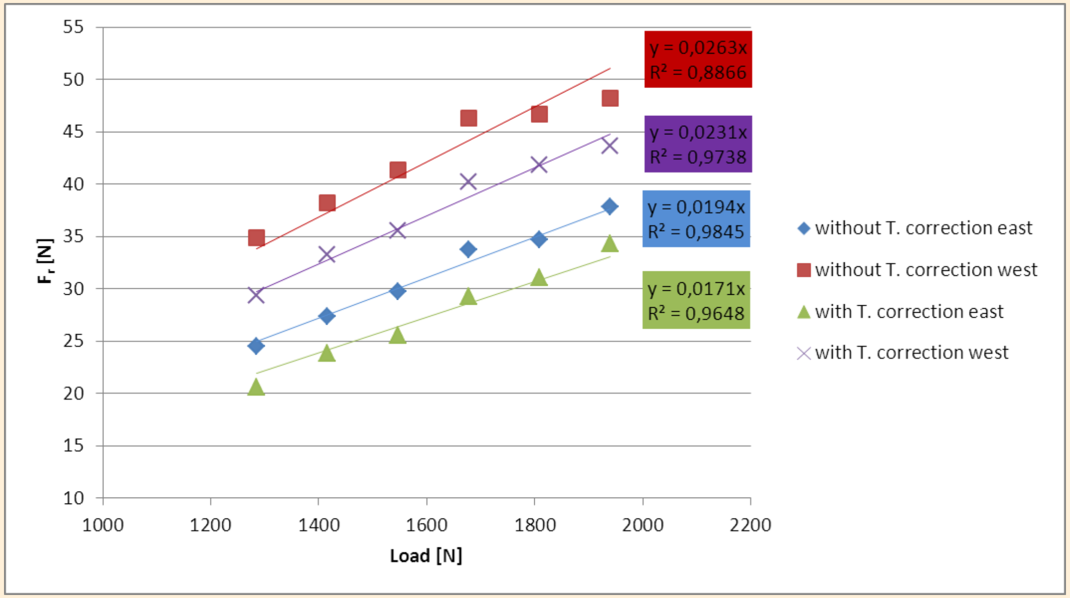
- **Part II:**
  - 2 measurement campaigns
  - other test sections (same as short term repeatability)
  - same group of researchers
  - 3 months
- **Repeatability is good (slope of approaches 1)**
- **Correlation is reasonable**



2. Trailer measurements

Tyre load

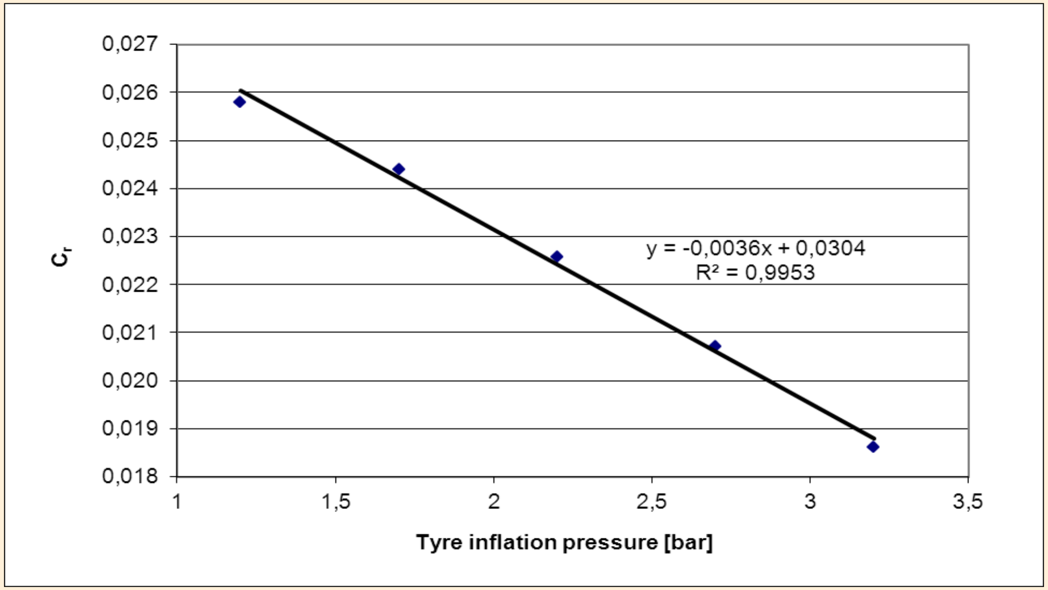
- **loads: 1285 N, 1416 N, 1547 N, 1678 N, 1809 N and 1939 N**
- **2 directions of street: east and west**
- **influence load on RR force is linear**
- **C_r constant and more or less independent of the load**
- **applying temperature correction yields better correlation**



2. Trailer measurements

Tyre inflation pressure

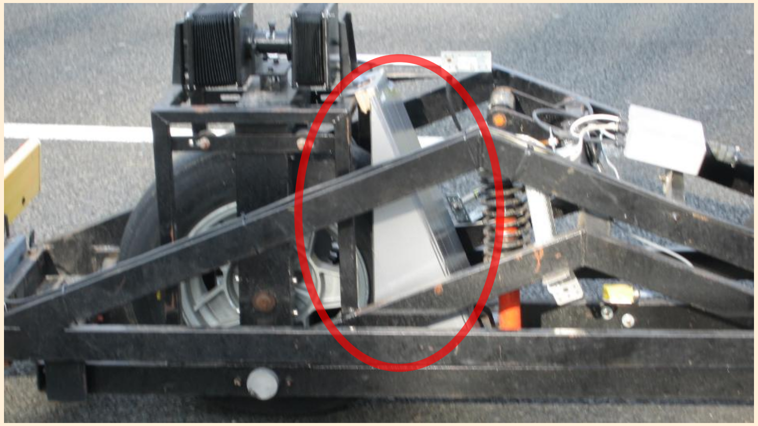
- **1.2 bar - 3.2 bar (in steps of 0.5 bar)**
- **tyre inflation pressure decrease = C_r increase**
- **1 bar difference = approx. 0.004 raising or lowering of C_r (15 - 20 %)**
- **tyre inflation pressure very important factor for RR**
- **tyre inflation pressure increases with temperature -> good warm-up procedure**

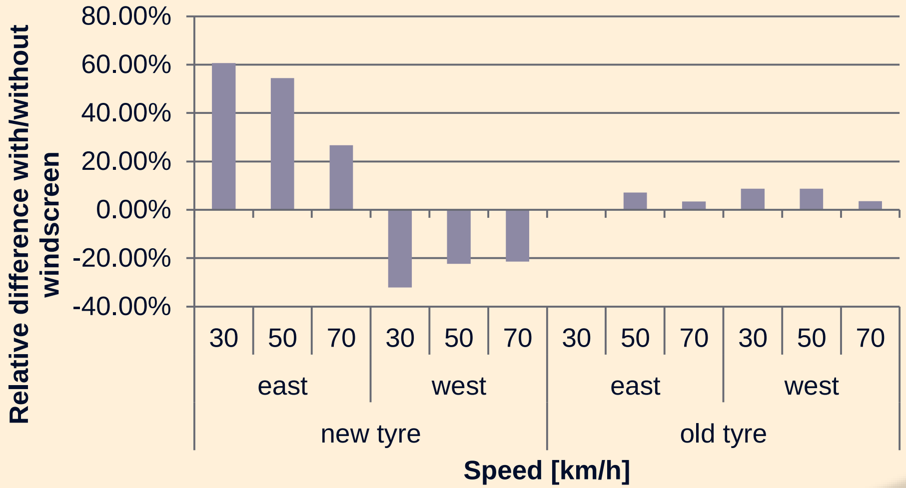


2. Trailer measurements

<u>Wind shielding</u>

- removable wooden windscreen
- measurements with old and new tyre at 30, 50 and 70 km/h
- eastern wind during measurements with new tyre
- generally C_r higher without windscreen
- windscreen absolutely necessary for measurements, but windscreen all around tyre and to ground level would even be better

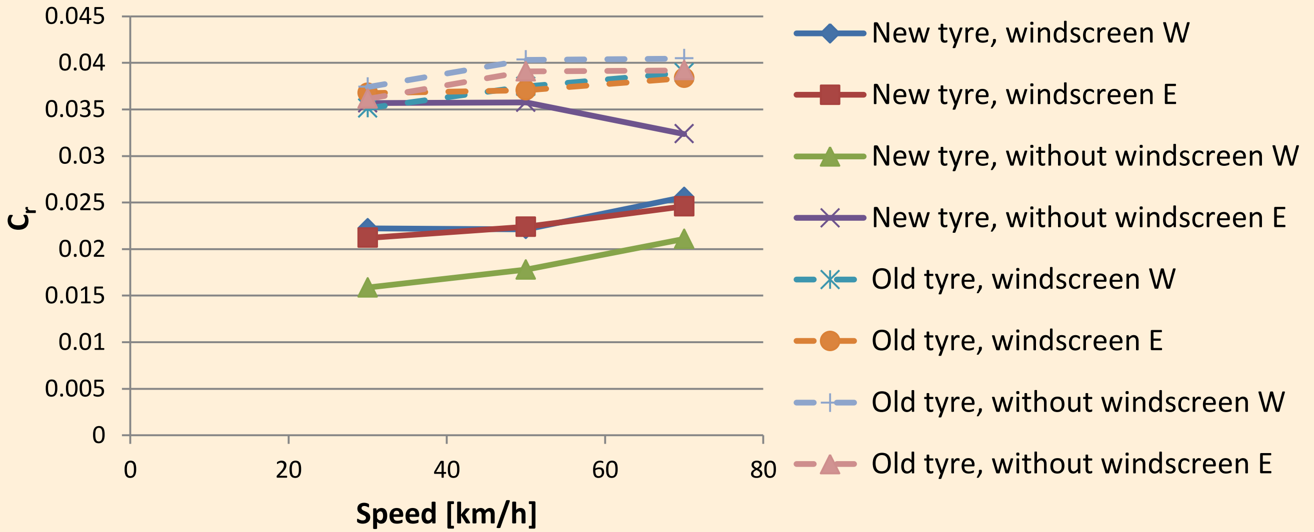




2. Trailer measurements

<u>Speed</u>

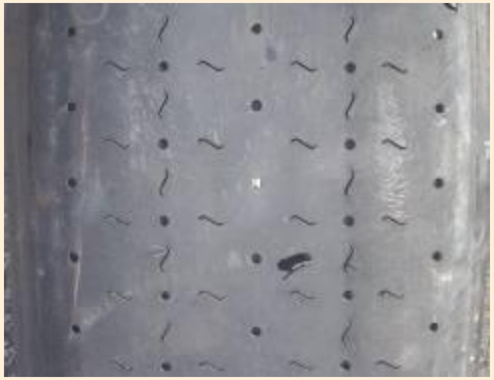
- measurements with old and new tyre at 30, 50 and 70 km/h with/without windscreen
- generally C_r increases when speed increases (except for one measurement without windscreen)
- more recent research [MIRIAM]: larger windscreen (encapsulating whole tyre) advisable to eliminate wind influence at higher speed



2. Trailer measurements

Tyre type

- **old tyre: slick Michelin SB-15/63-14X, about 30 years old**
- **new tyre: Michelin Energy Saver 195/70 R14 91T**
- **C_r values new tyre lower than old tyre**
- **not only road surface important share on RR, also tyre**
- **well thought selection of tyre can provide lower CO2 emission**



old tyre

new tyre

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3. Coast down measurements

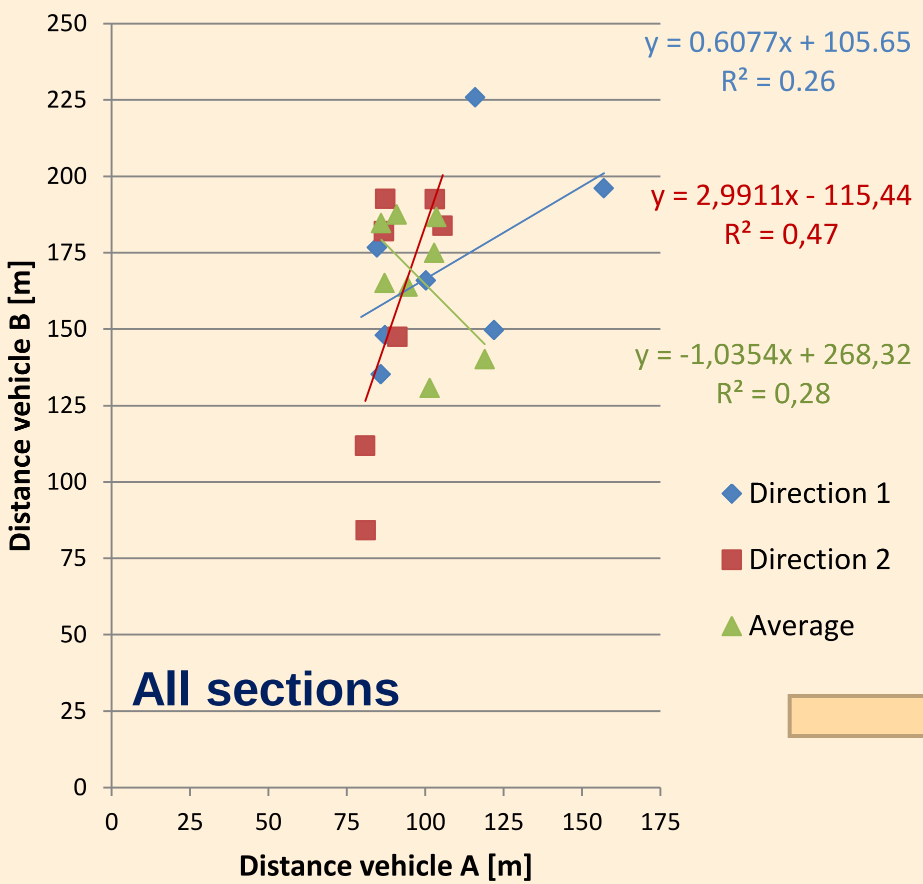
- Always same driver, fuel tank filled up before start
- Tyre pressure – cold condition
- At least 10 km to warm up tyres
- Length test sections 100 to 200 m
- Initial speed 20 km/h vehicle A and 25 km/h vehicle B
- Clutch pedal pushed, coasted from start point until standstill, distance measured
- To eliminate influence slope, measurements in 2 directions >< because of safety on opposite driving lane
- 3 coast down measurements in each direction
- Dry weather conditions and low wind
- Ambient air temperature: 5.6 - 20.5 °C >< no temperature corrections

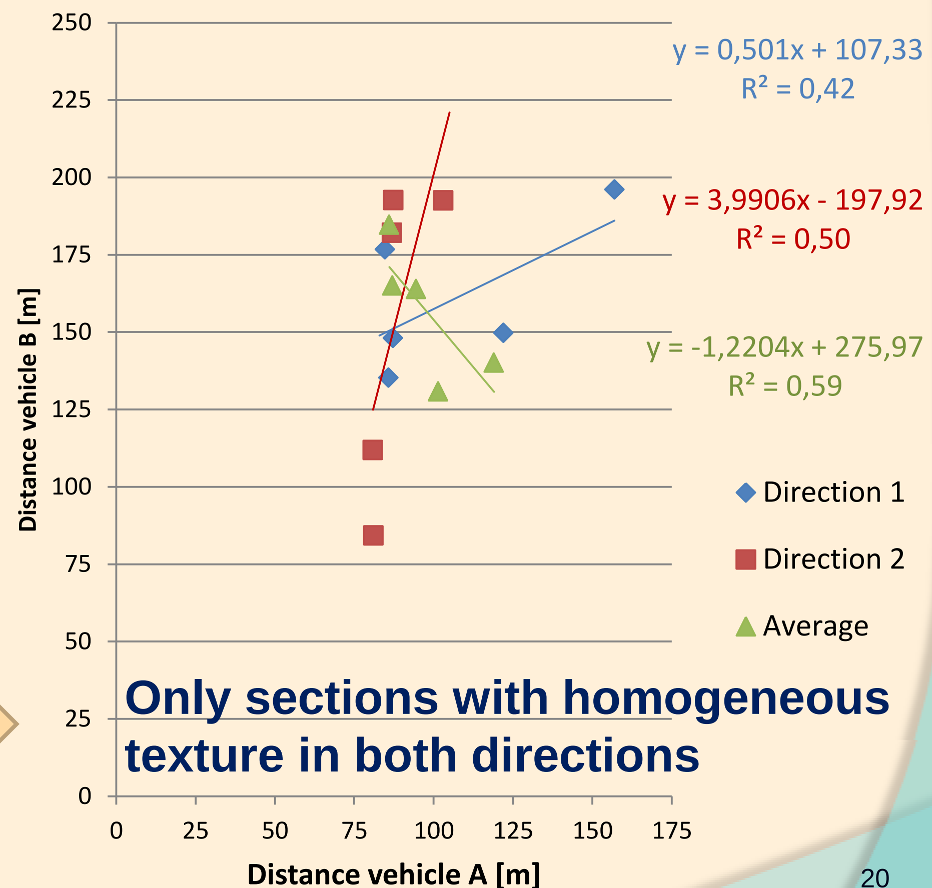
3. Coast down measurements

	Vehicle A	Vehicle B
Vehicle type	Audi A3 S-Line (2003)	Peugeot 307 (2005)
Vehicle weight (driver included)	1480 kg	1400 kg
Picture of vehicle		
Tyre Inflation	2.5 bar	2.4 bar
Tyre type	Triangle 225/45ZR17	Michelin 205/55R16
Tread depth tyre	6.0 mm	4.8 mm
Picture of tyre		

3. Coast down measurements

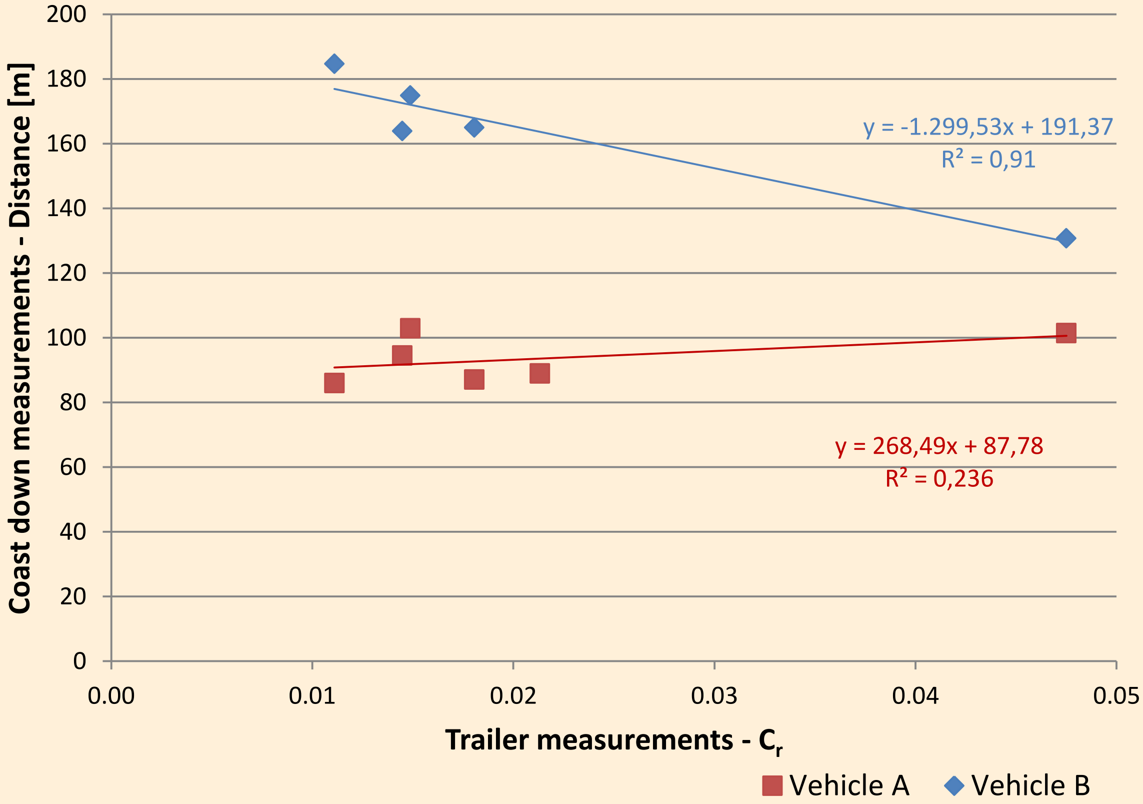
Corrrelation between measurements 2 vehicles





3. Coast down measurements

Corrrelation between coast down and trailer measurements



- 6 test sections in common
- Vehicle B shows good correlation (25 km/h)
- Low correlation vehicle A (20 km/h)
- Explanation:
  - vehicle A less accurate because of lower initial speed?
  - first measurements, operators not yet used to measurement method?

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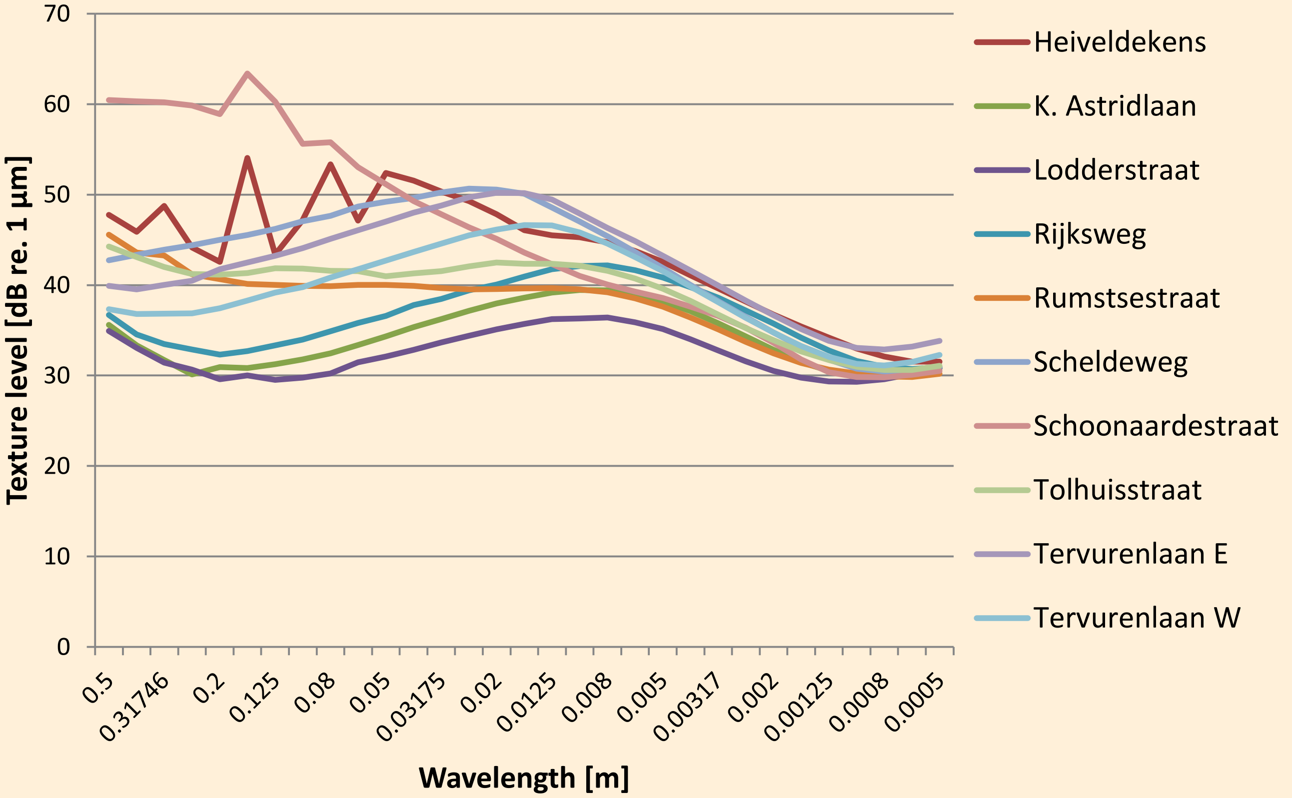
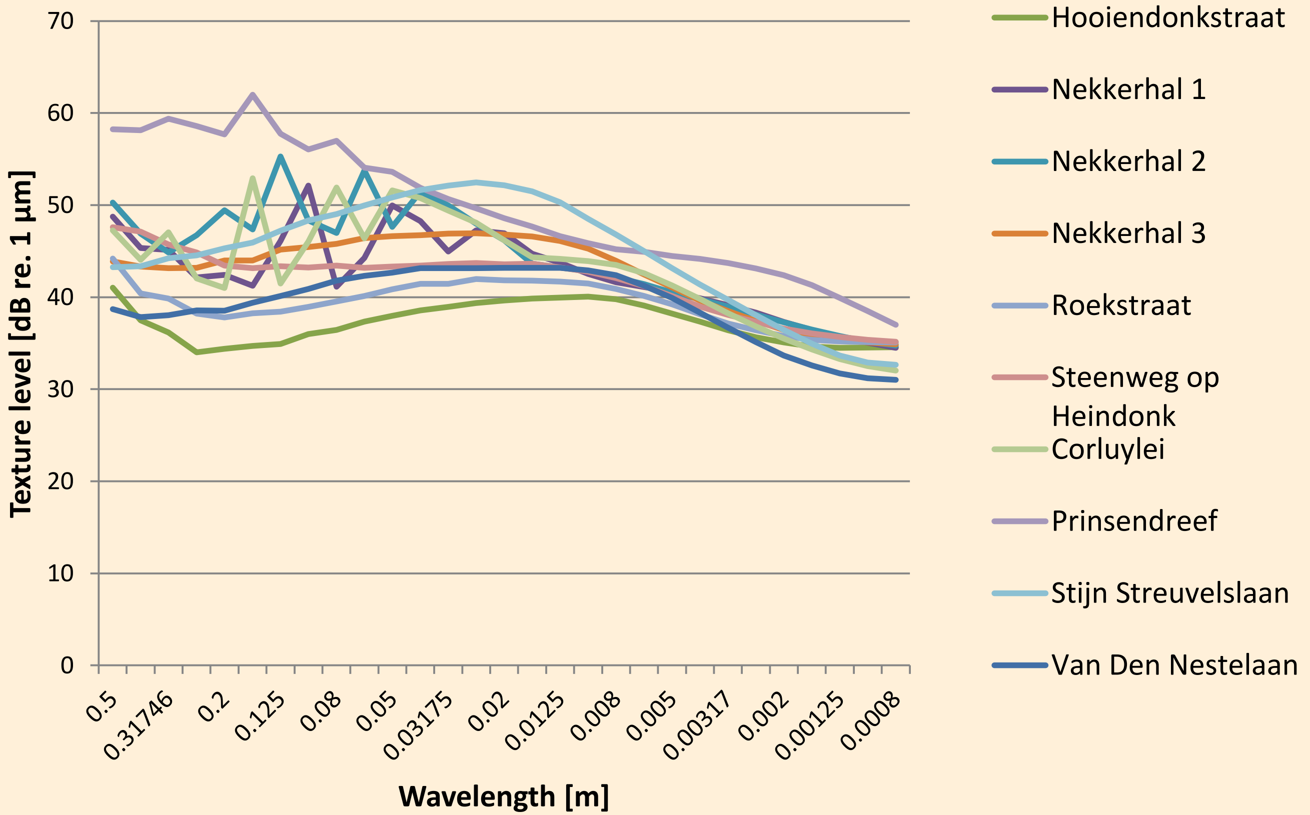
4. One-third-octave band texture levels

Texture measurements (trailer, De Bie – Hofmans)

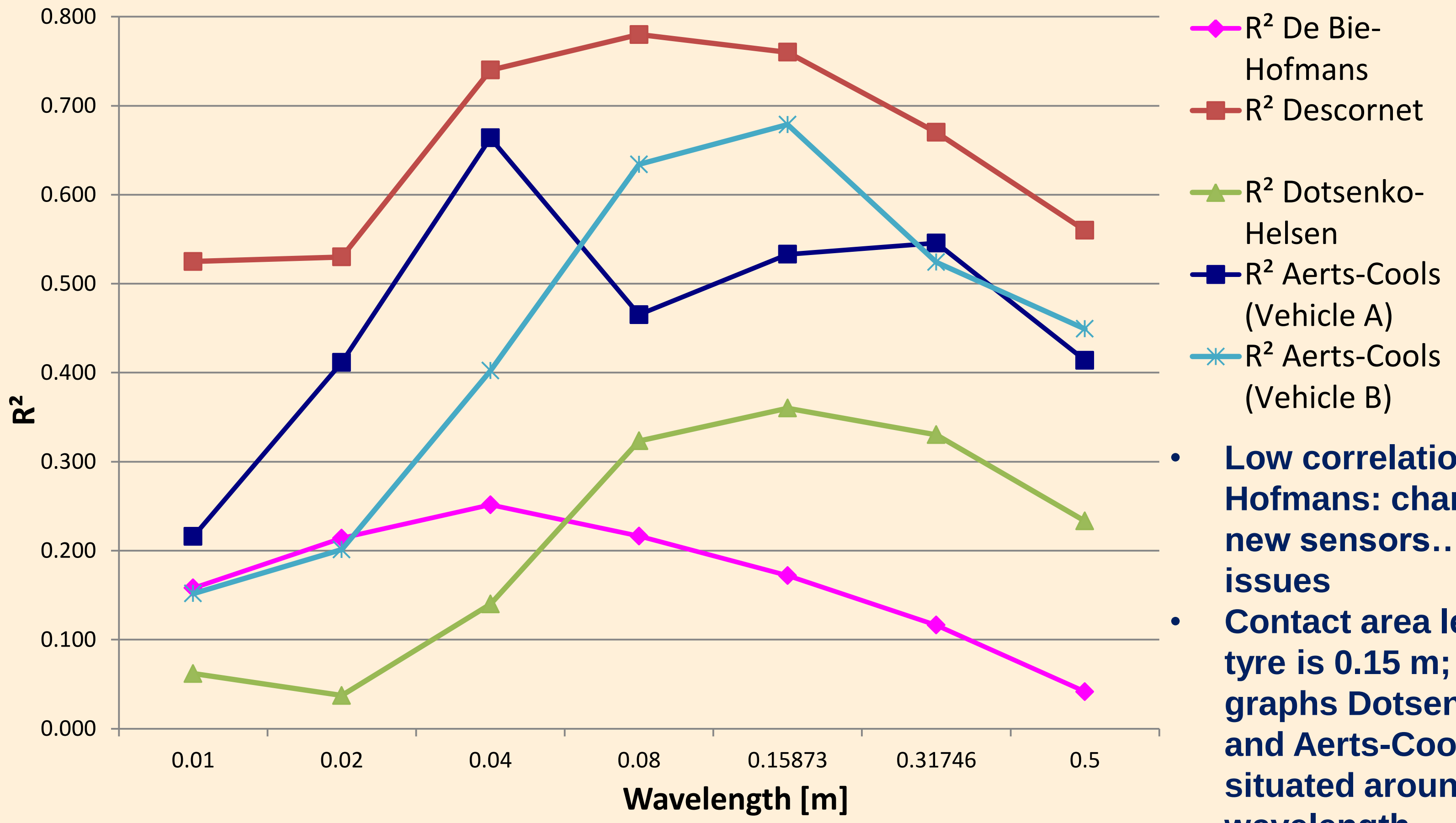


4. One-third-octave band texture levels

Texture measurements (coast down, Aerts – Cools)



4. One-third-octave band texture levels



- **Low correlations De Bie – Hofmans: change of tyre, new sensors… calibrations issues**
- **Contact area length of car tyre is 0.15 m; maxima graphs Dotsenko-Helsen and Aerts-Cools (B) are situated around 0.16 m wavelength**

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5. Conclusions

- **Long and short time repeatability reasonable**
- **Influence of load on RR force linear; C_r constant and more or less independent of load**
- **Tyre inflation pressure large influence; 1 bar difference = approx. 0.004 raising or lowering of C_r (15 - 20 %)**
- **Wind shielding necessary -> more accurate results at higher speeds**

5. Conclusions

- C_r increases slightly when speed increases; more research needed larger windscreen
- Selection of tyre – lower CO_2 emission
- Calibration very delicate, high influence
- Rudimentary coast down plausible RR results
- Very good correlations RR – megatexture (coast down, Dotsenko-Helsen, Descornet)

Thank you for your attention!