

Experimental Investigation of Pavement Surface Texture-Induced Rolling Resistance in a Battery Electric Vehicle

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Context



- > Energy consumed by a tire per unit of distance covered [1]
- > Up to **41%** of a passenger BEV's battery energy used to overcome rolling resistance [2]

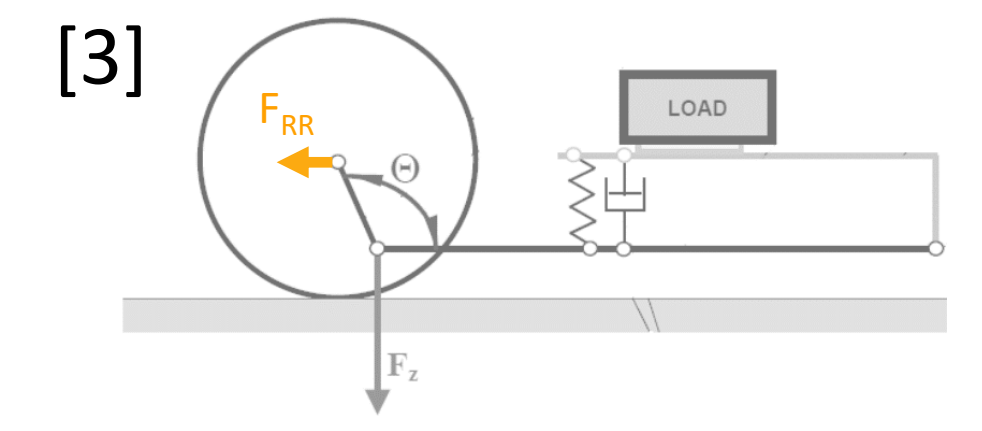
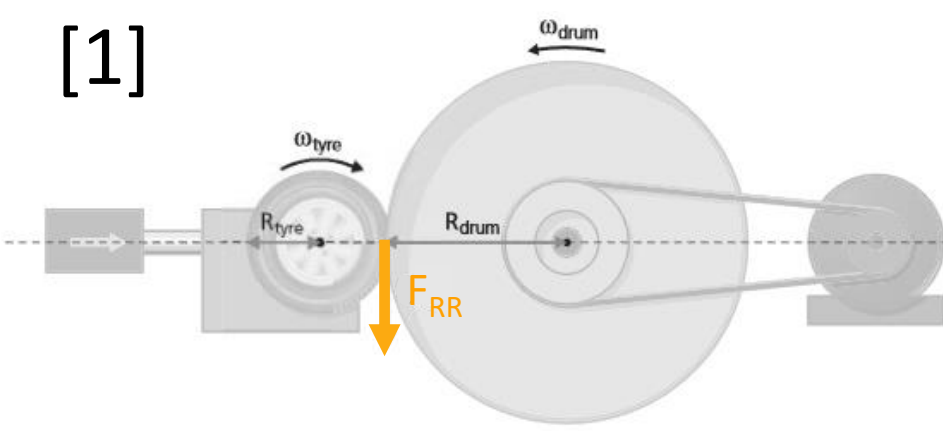
INFLUENCING FACTORS

- > Tread depth
- > Tread design
- > Tread compound
- > Inflation pressure
- > Temperature
- > Texture
- > Roughness
- > Stiffness
- > Temperature
- > Ambient temperature
- > Wind velocity
- > Wind direction
- > Velocity
- > Load
- > Load transfer

REFERENCE MEASUREMENT METHODS

Indoor: Drum method

Outdoor: Trailer method



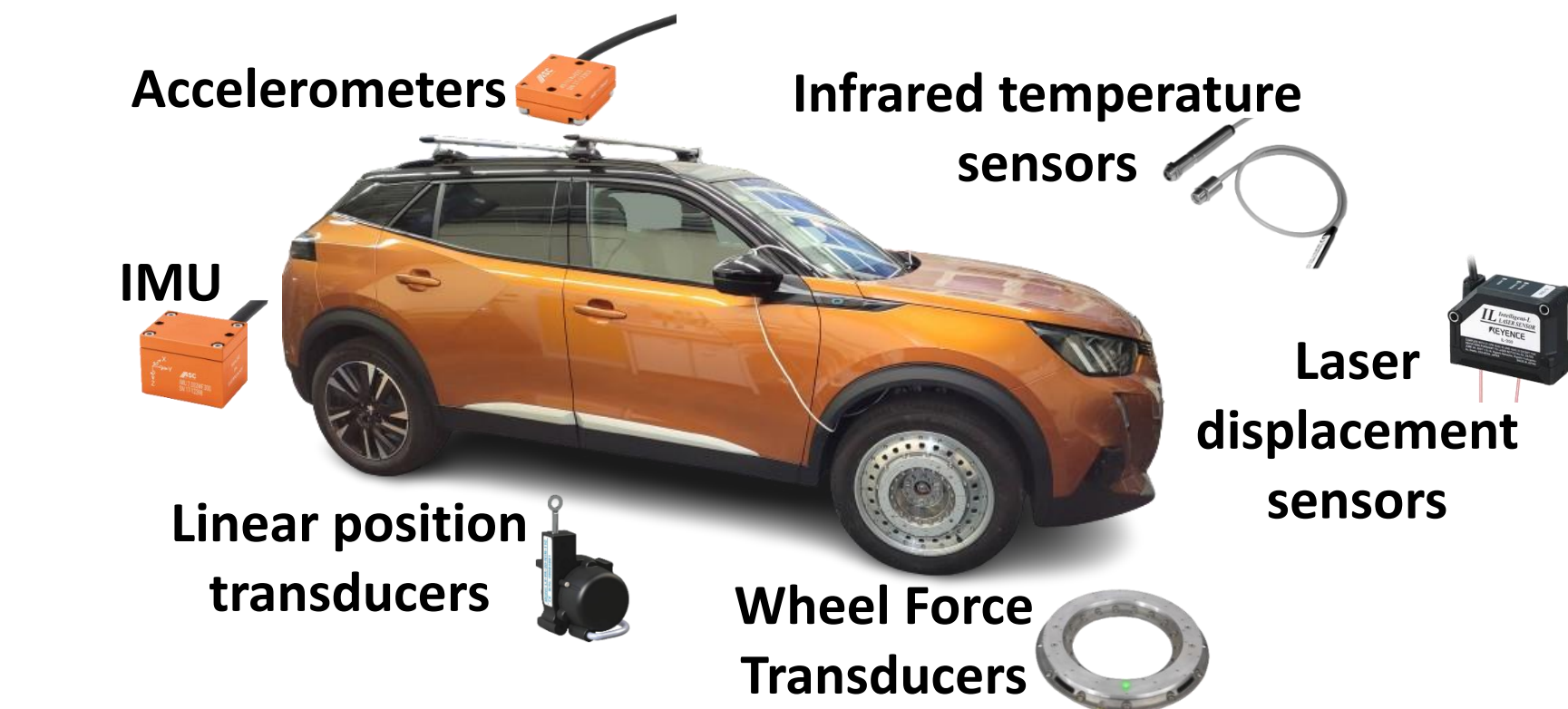
- > Lab test conditions
- > Component level
- > Not real tire-road interaction
- > Real operating conditions
- > Trailer specifically designed
- > Not real vehicle dynamics

Objectives

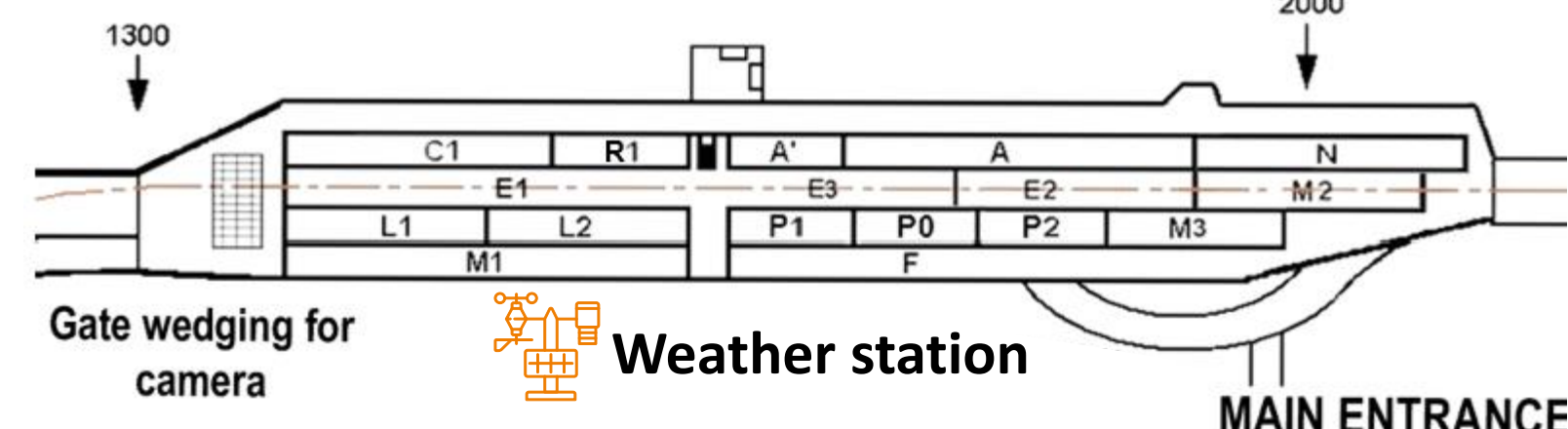
- > Set-up an outdoor vehicle-based testing procedure to measure rolling resistance
- > Evaluate effects of pavement surface texture on the rolling resistance in a BEV
- > Develop a machine learning-based rolling resistance prediction model

Methodology

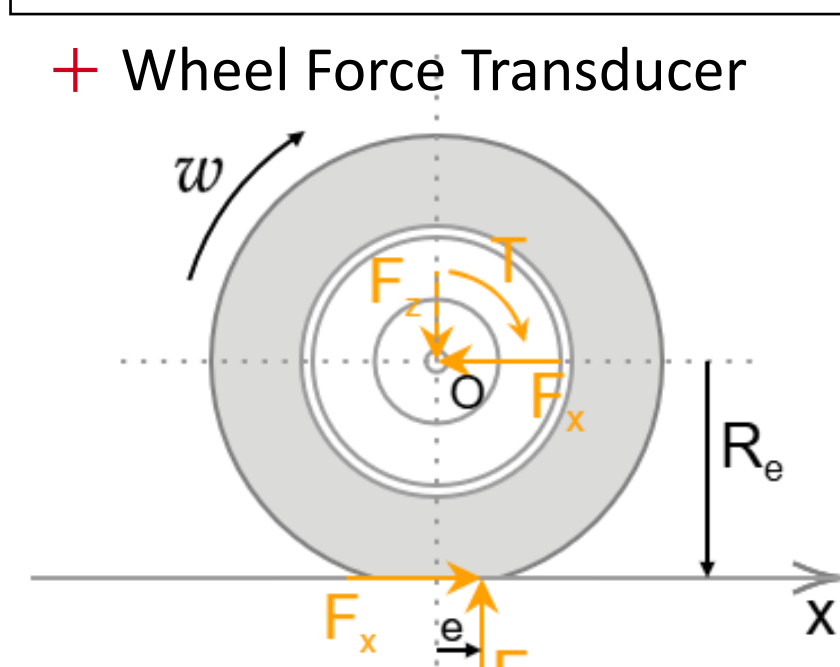
Instrumented BEV



Test Boards Area: 700m



ROLLING RESISTANCE MEASUREMENTS



$$T = F_x R_e + F_z e \quad M_y = F_z e$$

$$F_{RR} = F_z \frac{e}{R_e} = \frac{T}{R_e} - F_x$$

$$RRC = \frac{F_{RR}}{F_z}$$

T : Driving torque F_z : Normal force
 F_x : Longitudinal force R_e : Dynamic tire radius
 M_y : Rolling Resistance moment
 F_{RR} : Rolling Resistance force
 RRC : Rolling Resistance Coefficient

- > 30 minutes warm-up procedure
- > 3-5 repetitions for each test condition
- > v = 50-80 km/h
- > Steady-state wheel torque method
- > Both directions of travel
- > MPD = 0.13-3.30 mm

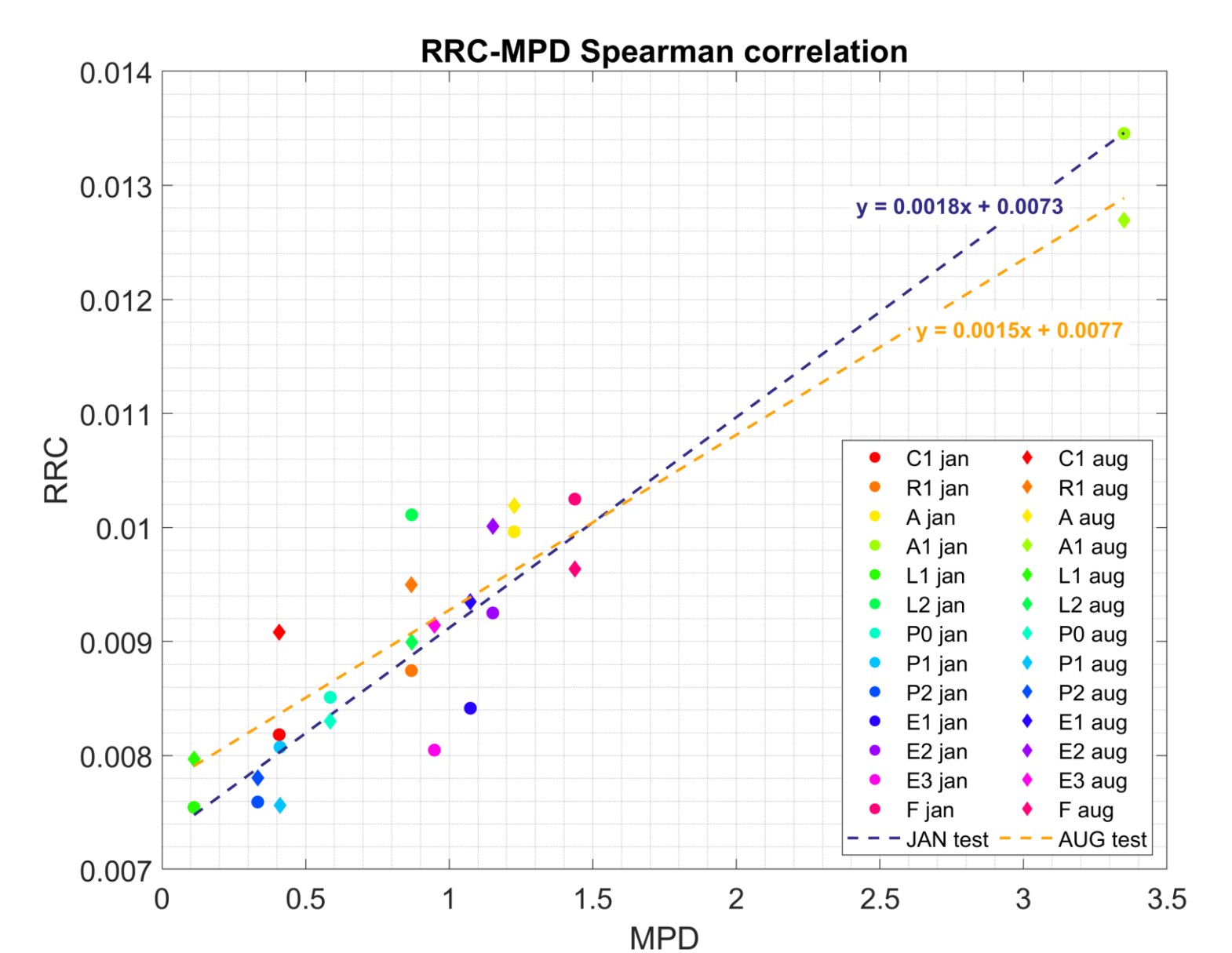
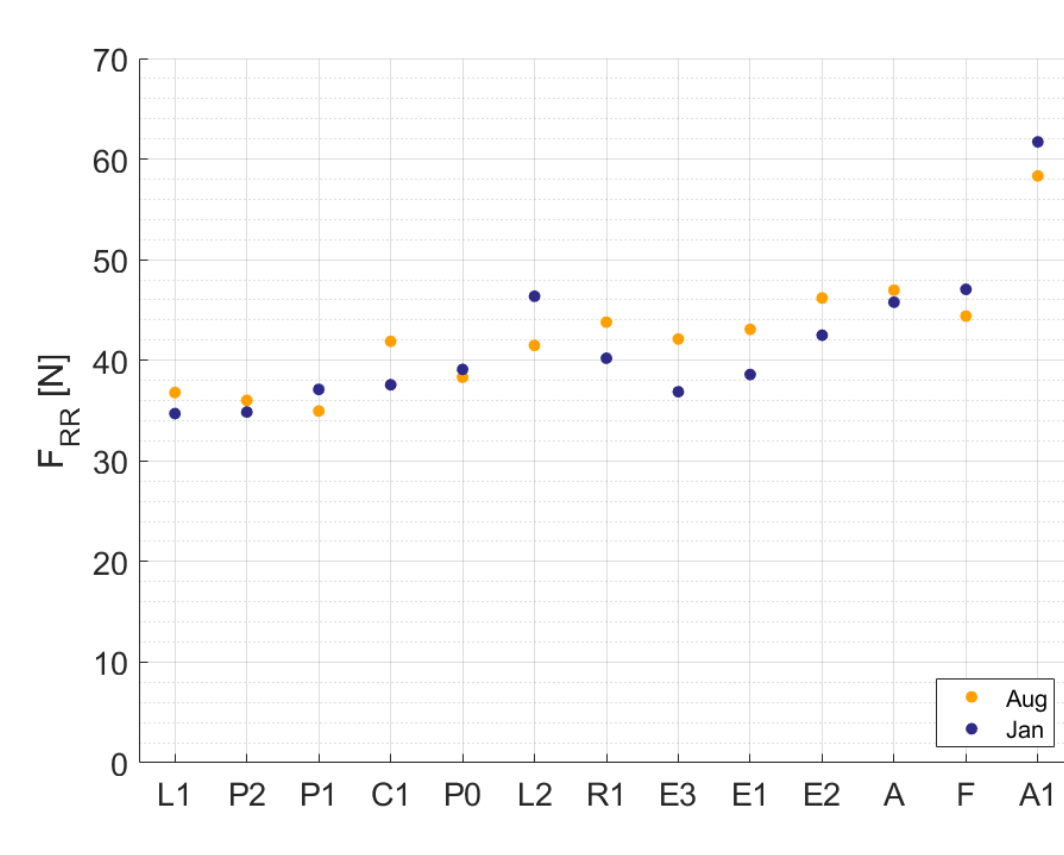
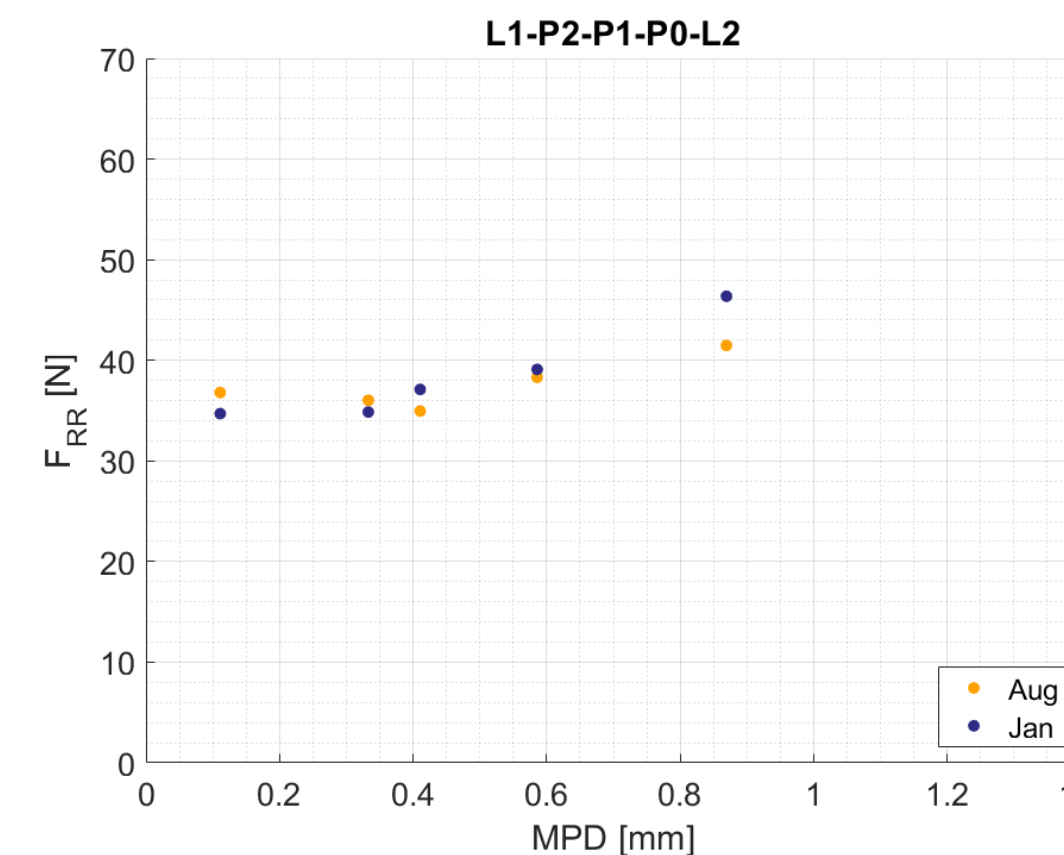
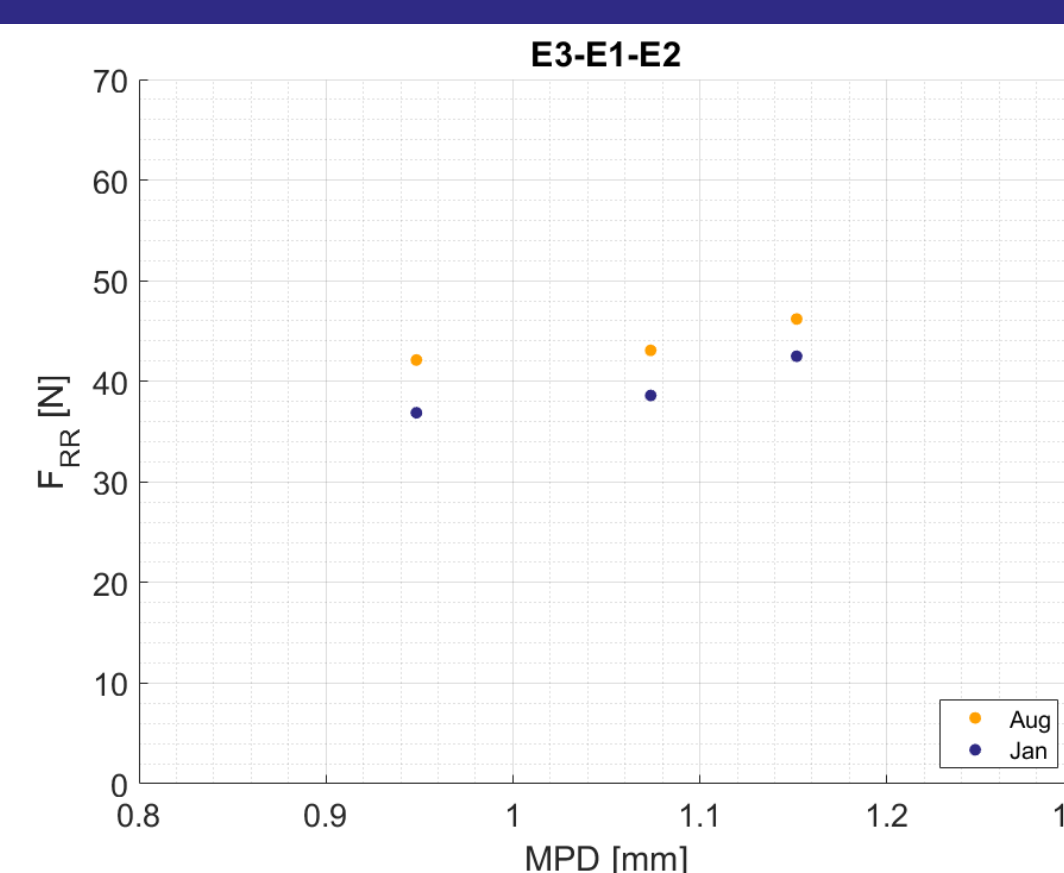
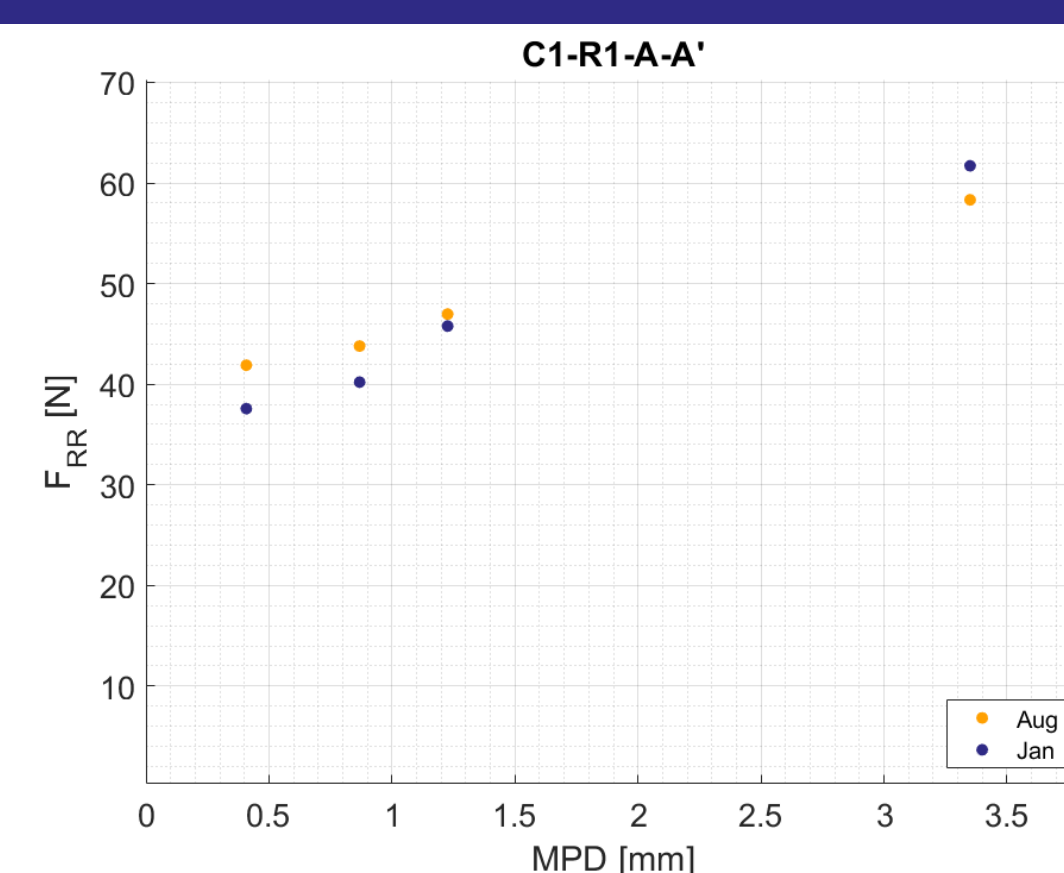
Results

JAN/AUG TEST CAMPAIGNS:

Averaged data on:

- > Repetitions
- > travel direction
- > section length
- > v = 50 km/h
- > T_{amb} Jan = 13 °C
- > T_{amb} Aug = 23 °C

- > F_{RR} increases with increasing MPD
- > F_{RR} values consistent with literature (1% F_z)
- > Different behavior P1, L2, F, A1 in Jan - Aug
- > RRC trend consistent with trailer measurements performed on the same test sections [4]



- > JAN: $\rho = 0.82$, p-value < 0.001
- > AUG: $\rho = 0.88$, p-value < 0.001

Conclusions

- > Robust procedure providing insights for outdoor measurement standardization
- > Rolling resistance in a BEV increases linearly with increasing macrotexture
- > Next: training a Machine Learning model using acquired dataset

References

[1] Michelin, "Le pneu Résistance au roulement," 2003.

[2] Holmberg K. and Erdemir A., "The impact of tribology on energy use and CO2 emission globally and in combustion engine and electric cars", Tribology International 135, 389-396 (2019).

[3] Ronowski G., "Design and calibration of rolling resistance test trailer R2Mk. 2." IOP Conference Series: Materials Science and Engineering. Vol. 148. No. 1. IOP Publishing, 2016.

[4] Sandberg U., Bergiers A., Ejsmont J. A., Goubert L., and Zöller M. "Rolling Resistance: Measurement Methods for Studies of Road Surface Effects." (2012).

