University of Stuttgart
Institute of Automotive Engineering

Aerodynamics of high-speed trains with respect to ground simulation

Dennis Weidner[1]
Daniel Stoll[2], Timo Kuthada[2], Andreas Wagner[1]

[1] IFS, University of Stuttgart, Germany
[2] FKFS, Stuttgart, Germany

Outline

- Introduction
- Wind tunnel experiments
  - Methodology
  - Results
- CFD setup & validation
- Test case: bogie fairings
- Summary & conclusions

Introduction

Introduction

- Wind tunnel and moving model testing are used to assess and optimize aerodynamic characteristics of high-speed trains
- Wind tunnel testing at model scale enables fast and repeatable measurements of aerodynamic forces and moments
- Only a few results of wind tunnel tests of high-speed trains using a moving ground are published

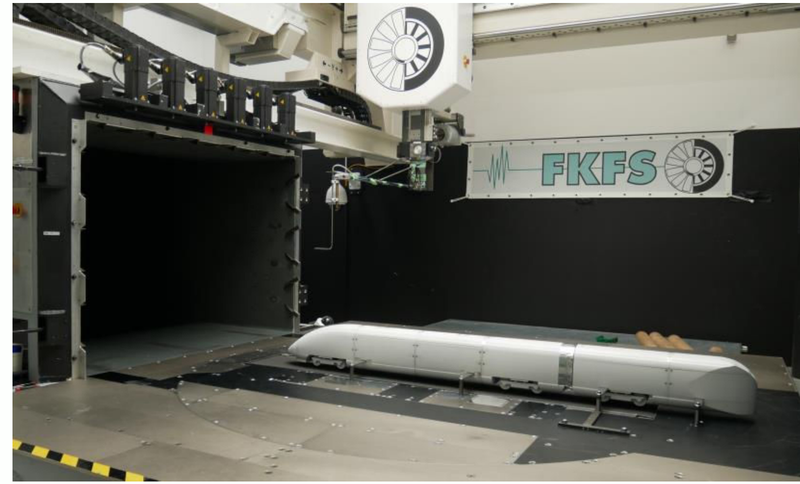
Objectives

- Conduct model scale wind tunnel experiments using a stationary and a moving ground, allowing for a direct comparison using the same model and wind tunnel
- Assess importance of moving ground
- Validation of CFD setup with moving ground measurements

Methodology

Model Scale Wind Tunnel of the University of Stuttgart

- ¾ open test section
- 1.654 m² nozzle (1.575 m x 1.050 m)
- Dynamic underfloor balance
- Up to 80 m/s, 50 m/s in following tests
- Ground simulation
  - Boundary layer suction system
  - 5-belt system (only center belt used in following tests)
  - Tangential blowing in front of center belt



Boundary layer height at turntable center	
Without ground simulation	*With ground simulation*
$\delta_{99\%} \approx$ 40 mm	Block profile

Model

- ICE 3 benchmark model geometry of EN 14067-6 crosswind assessment standard
  - Simplified geometry of ICE 3 high-speed train
  - First vehicle + downstream body of half length
- Small gap between bodies → no force transfer
- 1:20 scale model

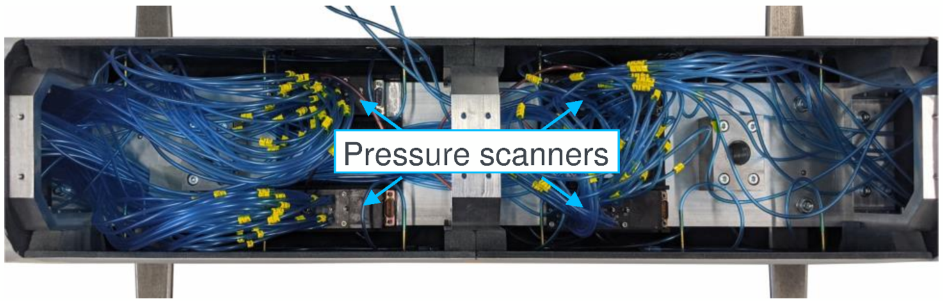
  → Blockage in Model Scale Wind Tunnel:

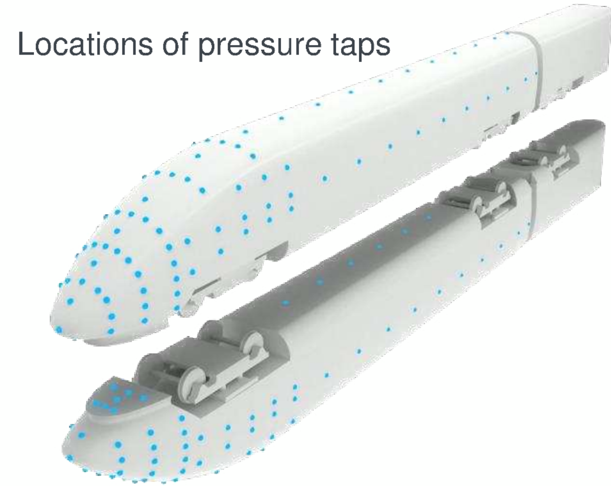
  1.5 % for 0° yaw

  7.6 % for 20° yaw (incl. downstream body)

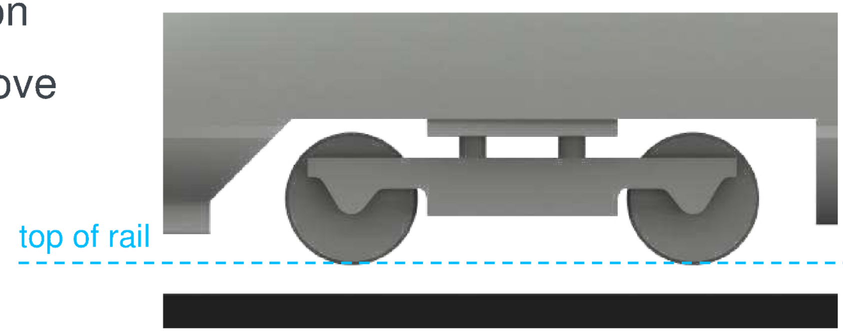
Model

- 125 pressure taps on first vehicle
- Differential pressure measurement system

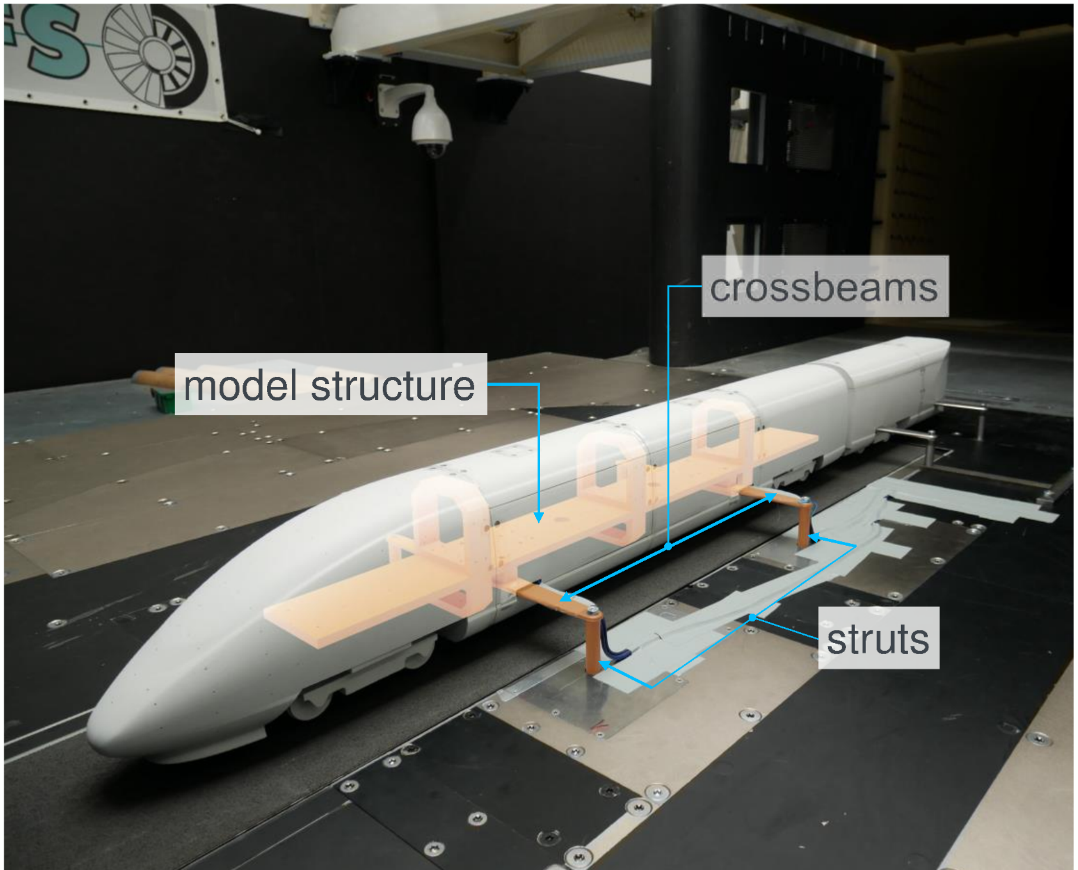




- „Flat ground with gap" ground configuration
  - Top of rail plane 235 mm (full-scale) above ground
  - Ballast and rails omitted



Model Mount



- First car connected to underfloor balance through crossbeams and struts
- Downstream body supported by wind tunnel floor

Measured forces

Forces on first car, crossbeams and struts

→ Sufficient to evaluate configuration changes

Model Mount

- First car supported by model manipulator
- No contact between the first car‘s model structure and crossbeams

Measured forces

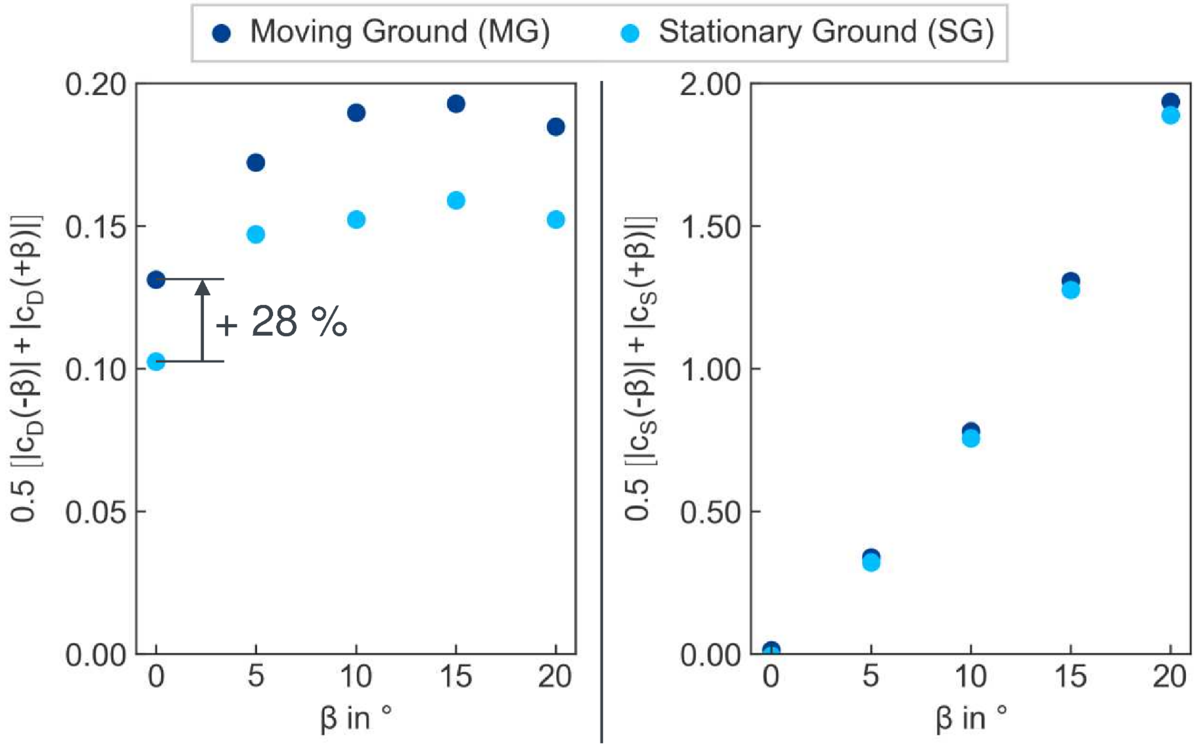
Forces on crossbeams and struts

→ Required for absolute measurements

Results

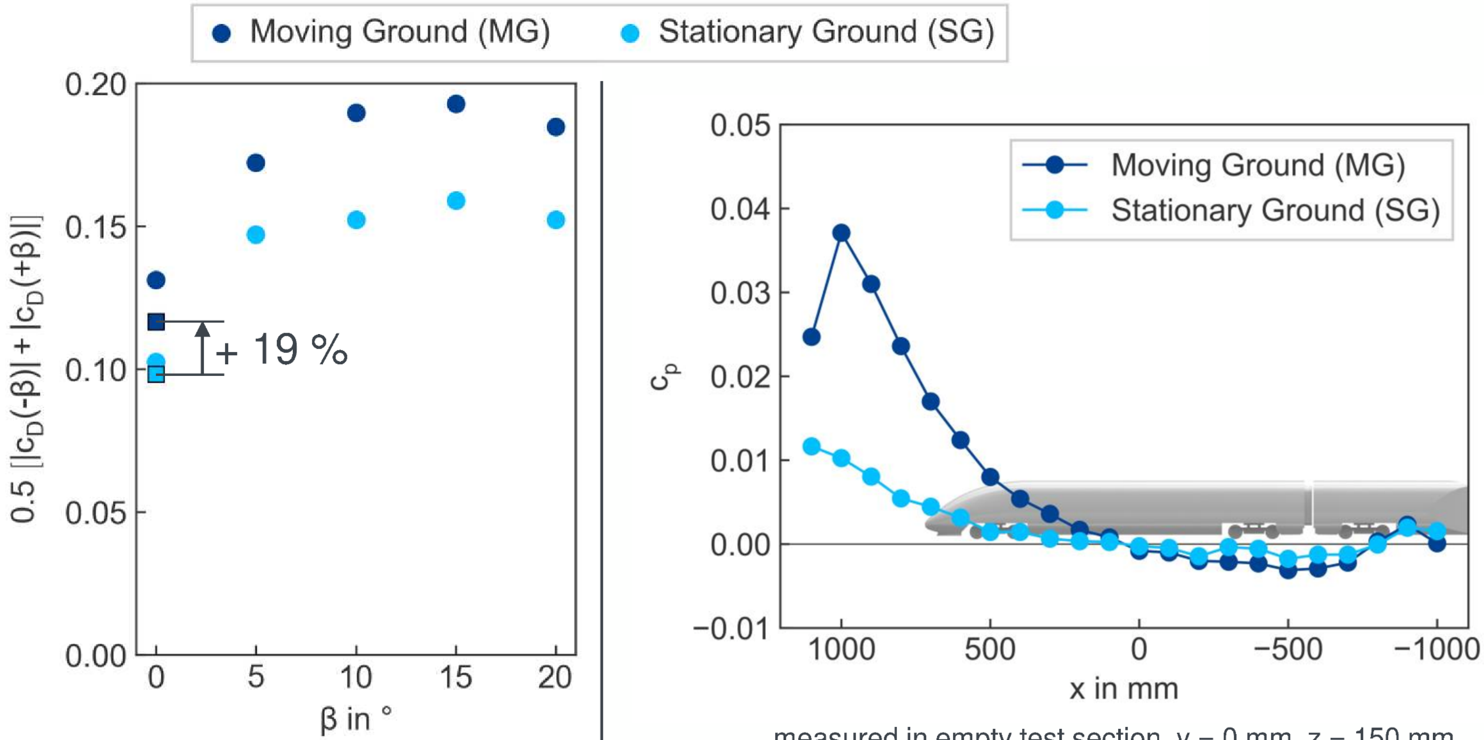
Results

Drag & Side Force Coefficients



Results

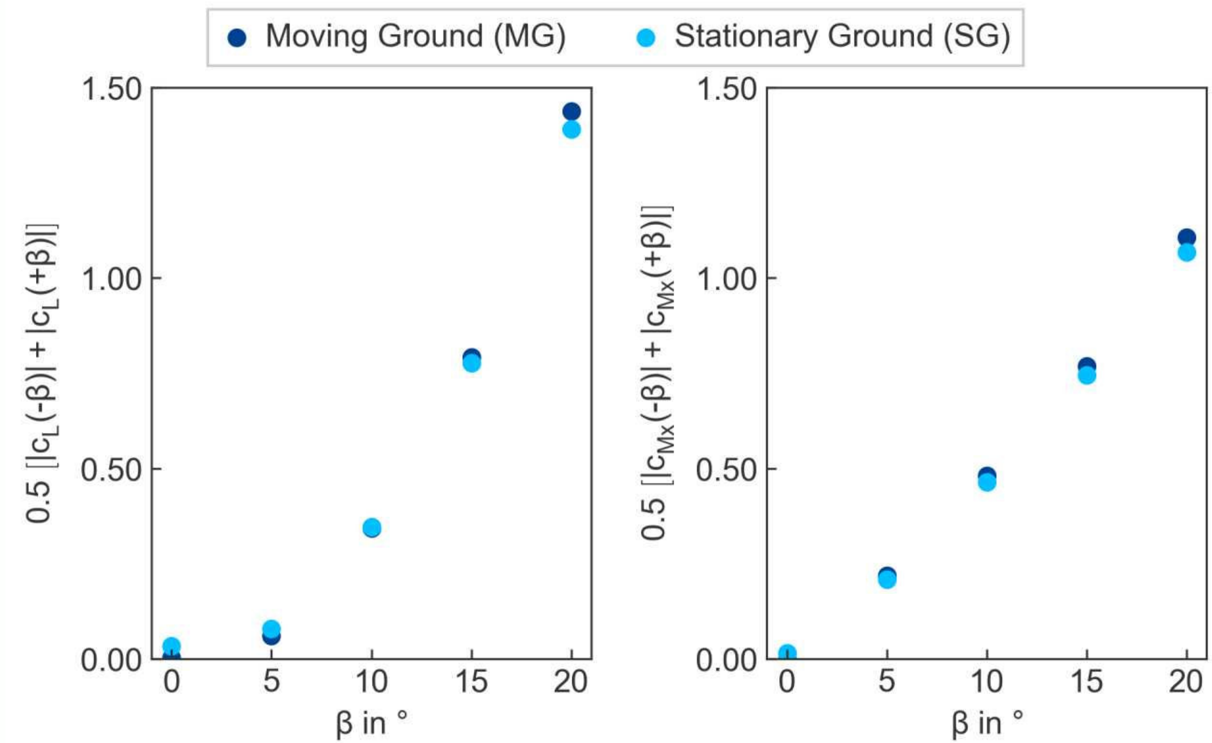
Drag & Side Force Coefficients



measured in empty test section, y = 0 mm, z = 150 mm

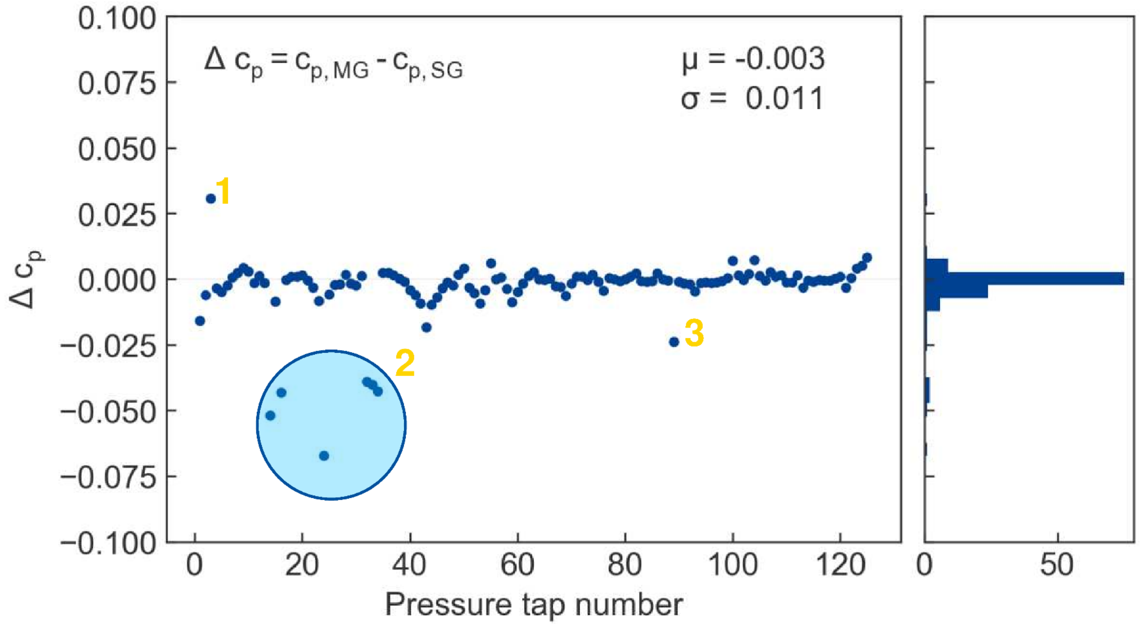
Results

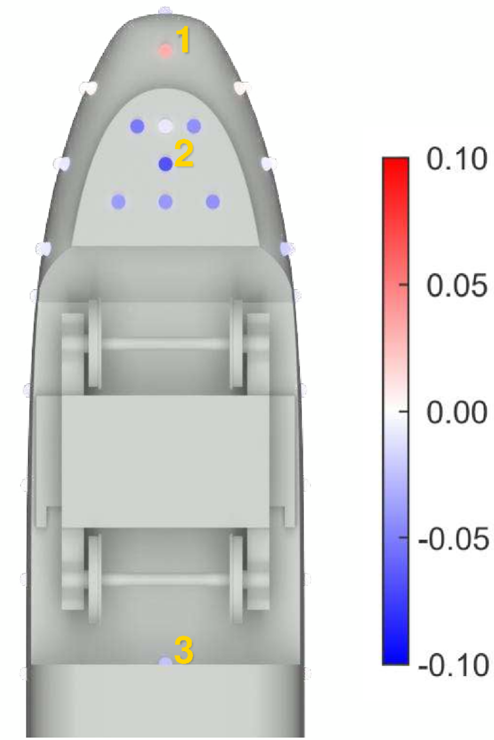
Lift & Rolling Moment Coefficients



Results

Pressure taps (β = 0°)

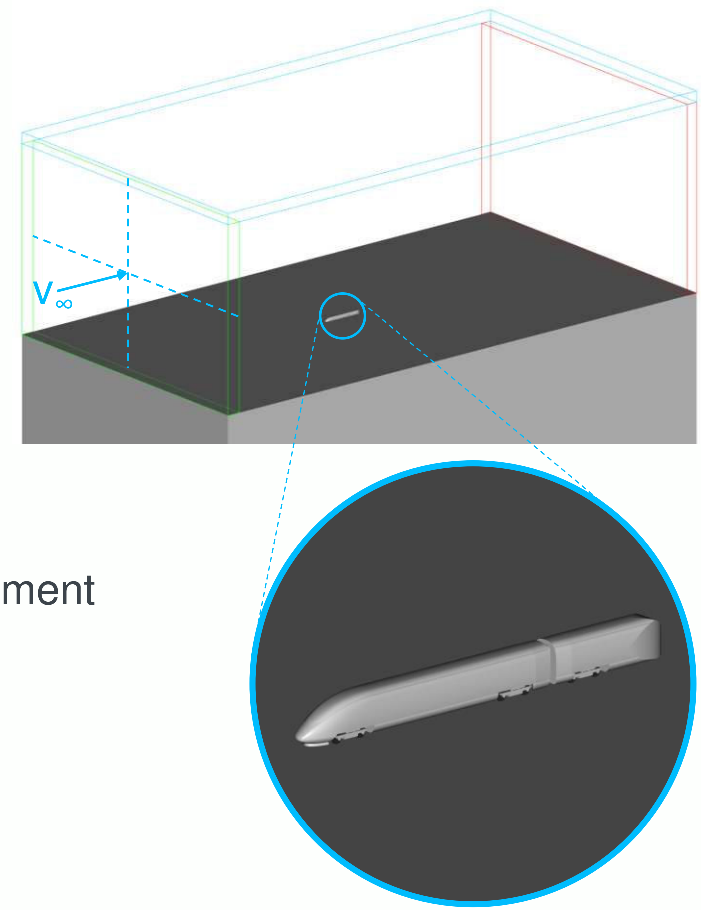




CFD Setup & Validation

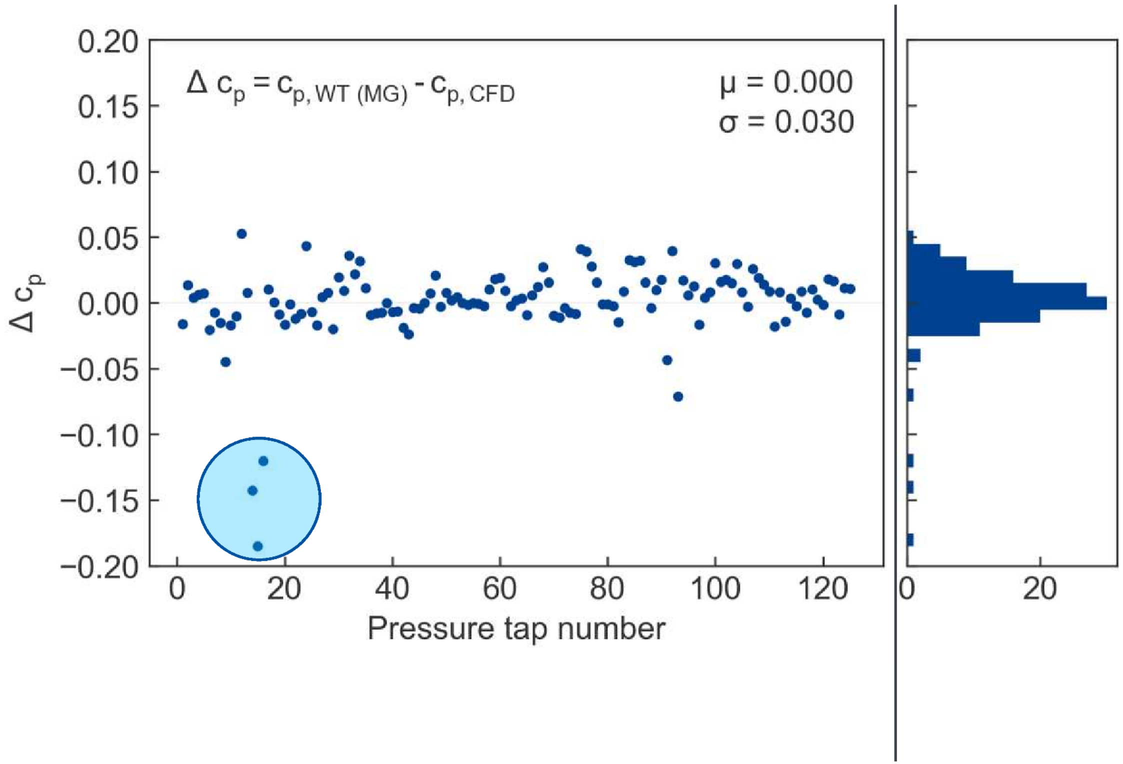
CFD Setup

- PowerFLOW 5.5b
- 1:20 scale
- 50 m/s inlet velocity
- Idealized environment
  - Full moving ground
  - Without model mount
  - Blockage < 0.1 %
- Stationary wheels and axles as in wind tunnel experiment

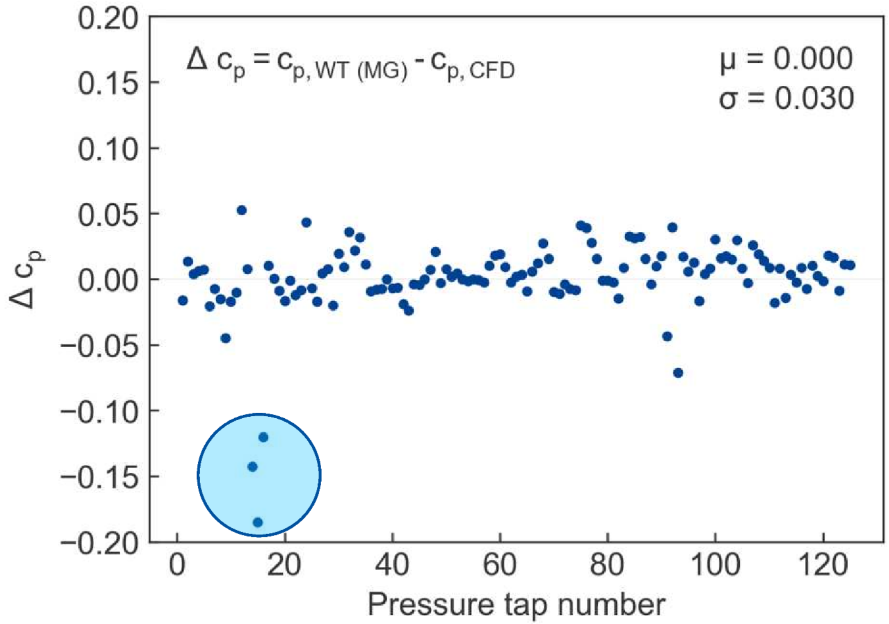


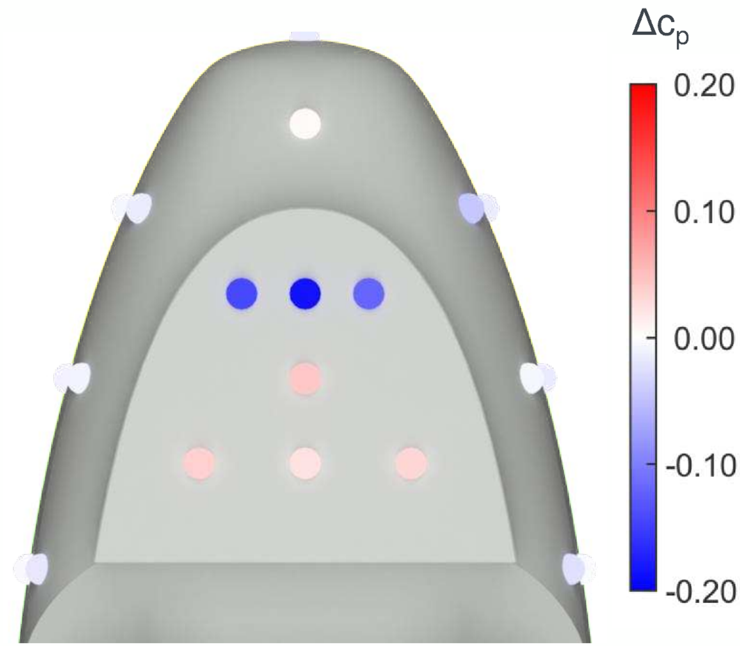
CFD Validation

Difference for pressure taps between moving ground measurements and CFD

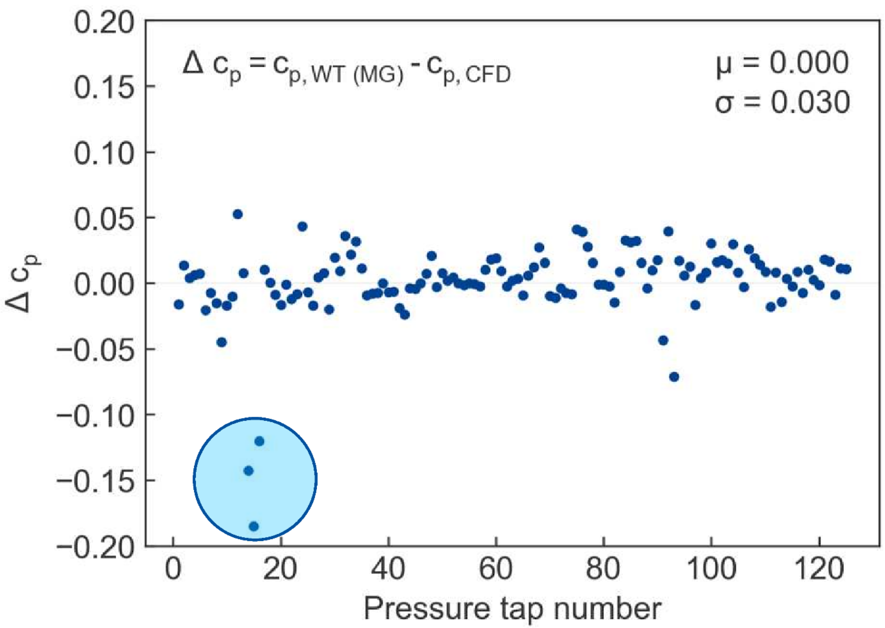


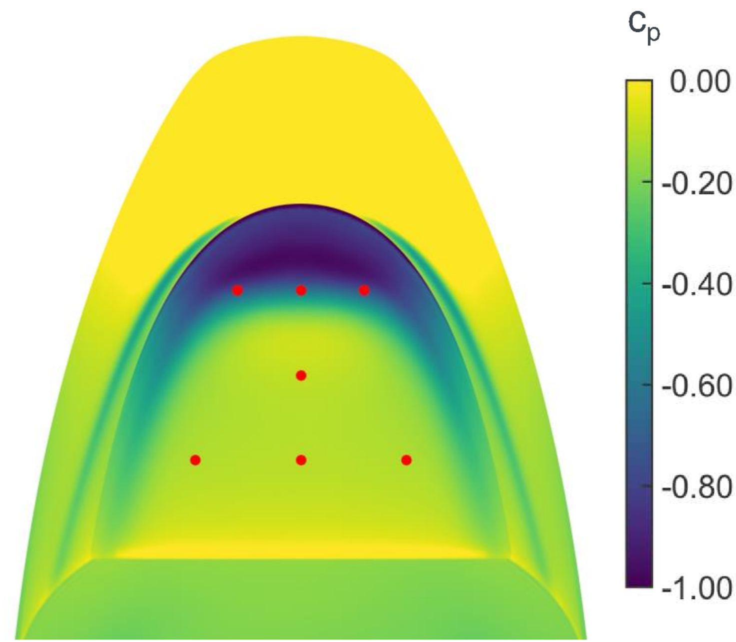
CFD Validation





CFD Validation





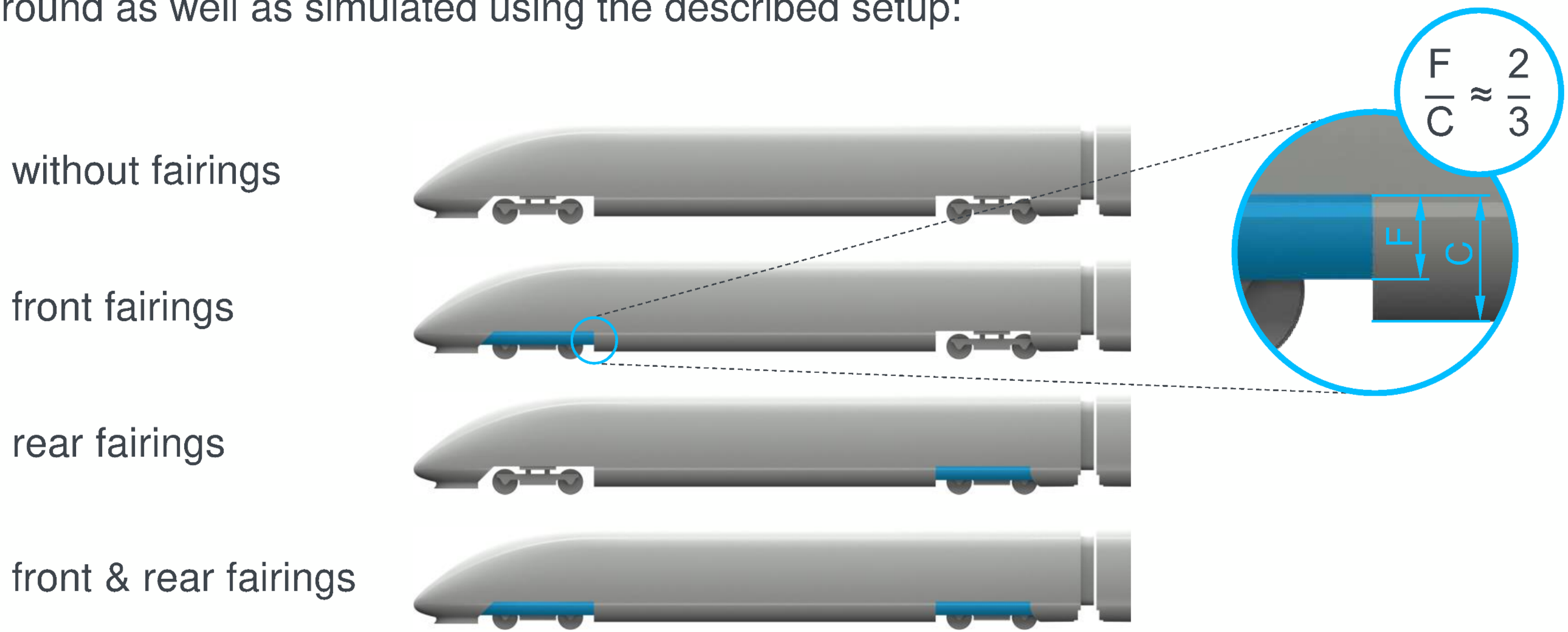
Moving the middle tap 2.5 mm upstream would result in same pressure as in wind tunnel experiment

Test Case: Bogie Fairings

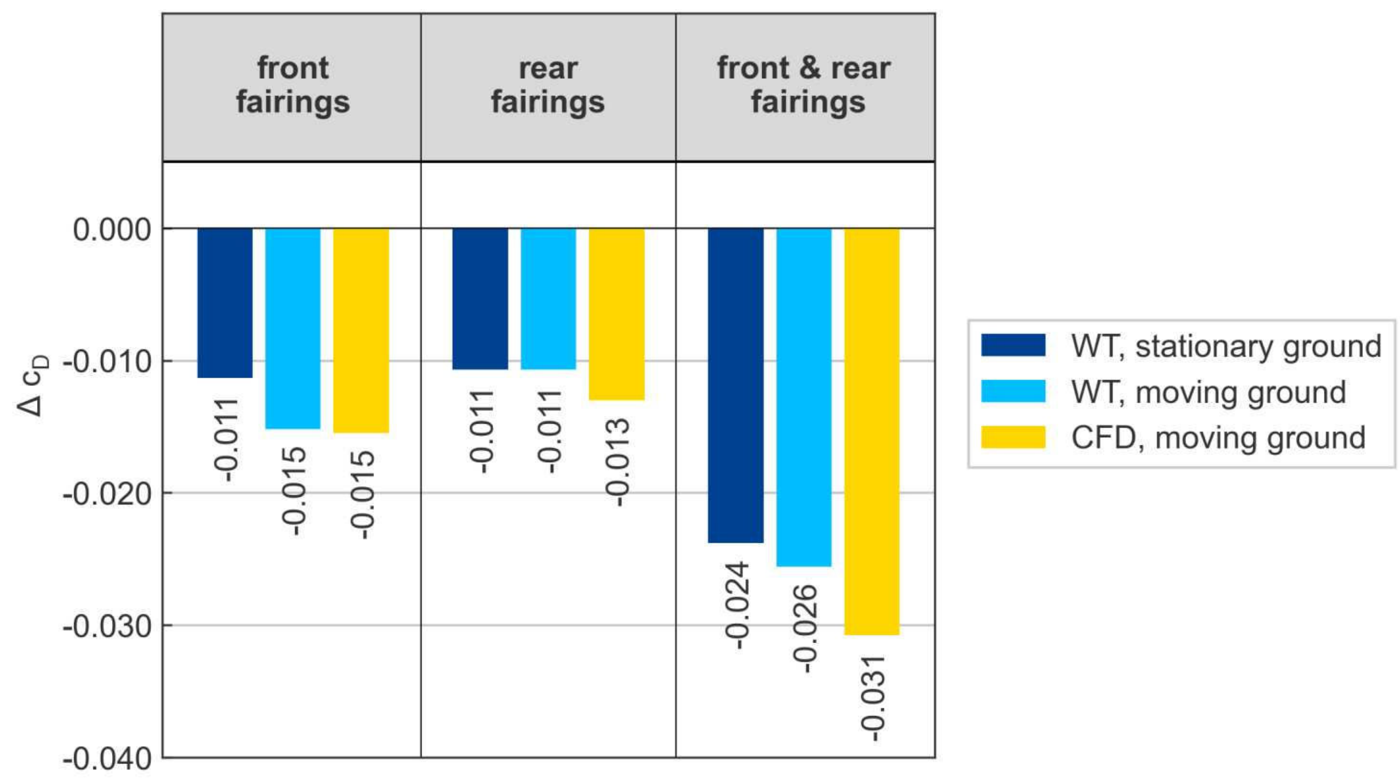
Bogie Fairings

Configurations

The following configurations were tested in the wind tunnel with stationary and moving ground as well as simulated using the described setup:



Bogie Fairings



Summary & Conclusions

Summary & Conclusions

Summary

- Wind tunnel tests using a stationary and a moving ground were conducted
- Comparison of wind tunnel measurements with respect to ground simulation
- Validation of CFD setup with pressure taps of moving ground wind tunnel tests
- Evaluation of bogie fairings

Conclusions

- Ground simulation has…

  … significant effect on drag

  … small impact on side and lift force as well as rolling moment
- Moving ground is important to evaluate bogie fairings
- Good agreement of idealized simulation with moving ground measurements