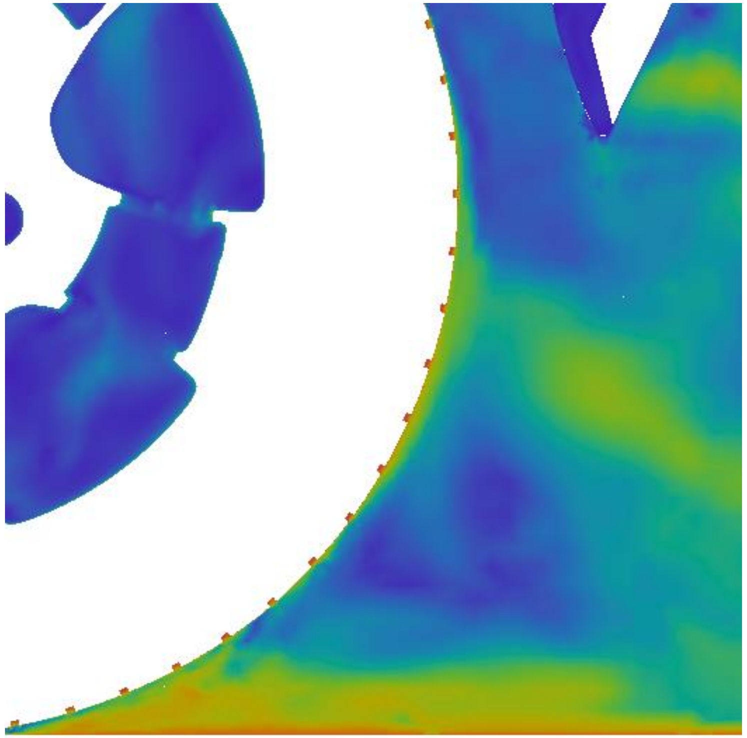
AN AUTOMATED METHOD FOR THE AERODYNAMIC MODELLING OF GROOVED TIRES

An efficient solution for the modelling of complex motion in vehicle applications



Thomas Schumacher, Pavlos Alexias

GOFUN

22/04/2020

About ENGYS

- Global providers of CFD products and services
- Founded in the UK (2009)
- Main focus on leveraging open-source software
  - FOAM/OpenFOAM developers since 1999
- 200+ customers worldwide
- 7 local offices
  - UK, Germany, Italy, USA, Australia, RSA, Brazil
- Well established resellers network
  - Japan, South Korea, China, USA, France, Spain

Engys Worldwide

engys®

What is HELYX?

- CFD software suite
- General purpose
- Enterprise product
- Highly scalable
- Cost effective
- Cloud ready
- Multi-platform
- Extendable
- In production since 2010

HELYX-GUI

HELYX-Core
ENGYS' open-source
CFD simulation engine

HELYX ADD-ONS
Add-ons for additional
functionality

User Support
Help Line

Code Maintenance
Regular software
updates and bug fixes

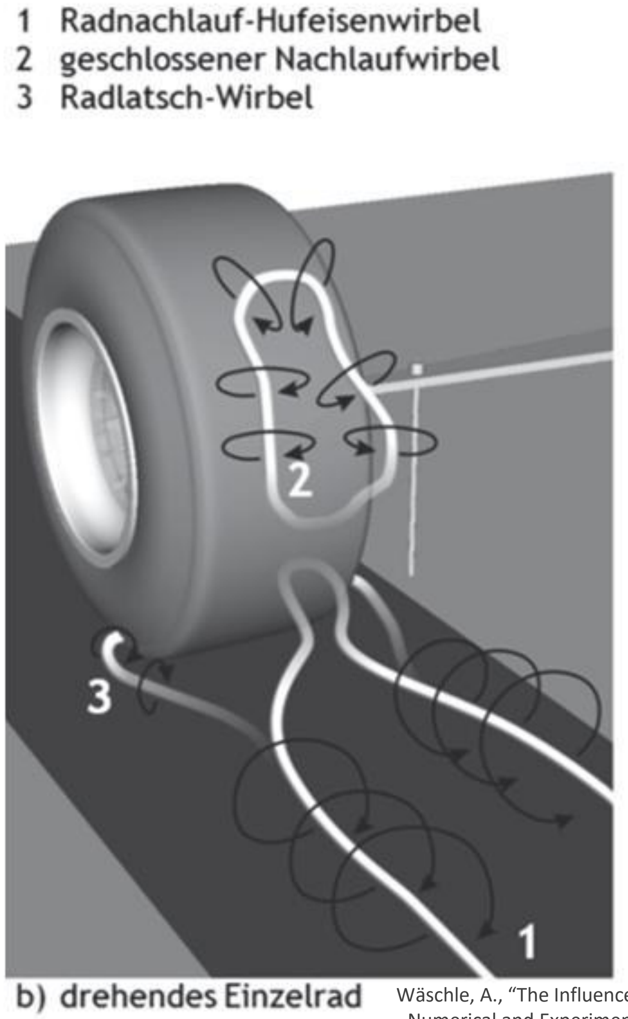
Documentation
Written user manuals
and tutorials guide

engys

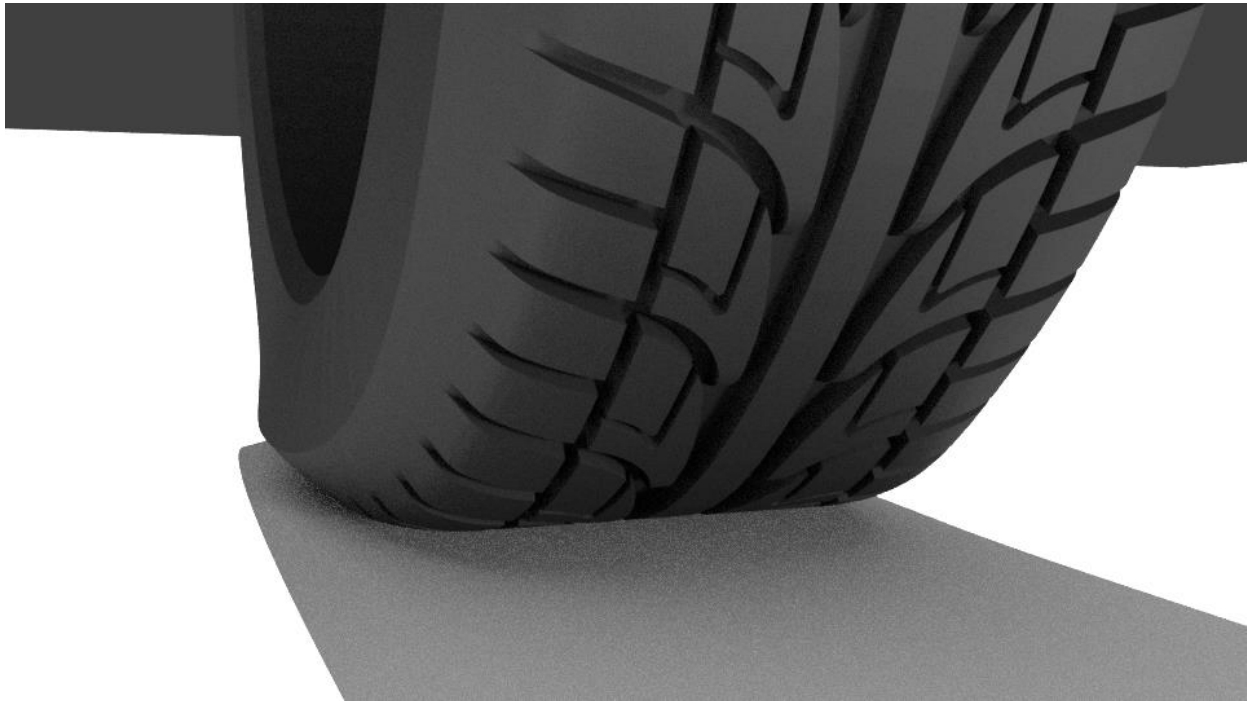
Overview

- Moving Reference Frames (MRF)
  - Rotation Approximation
  - Only rotationally symmetric zones
  - Convergence Slowdown
- Refactoring + Extended Functionality
- Two main features
  1. More Accurate + Easier Tire Modelling
  2. Vehicle Cornering

Introduction | Tire Modelling



Wäschle, A., “The Influence of Rotating Wheels on Vehicle Aerodynamics - Numerical and Experimental Investigations”, SAE World Congress & Exhibition, (SAE International, Apr. 2007), doi: 10.4271/2007-01-0107



Introduction | Tire Modelling

- Existing Methods
  - Rotating Wall (RW)
    - Easy implementation
    - Too inaccurate (no wall normal velocity)
  - Moving Reference Frame (MRF)
    - Good for tire's grooves
    - Difficult to set up
  - Sliding Mesh (SM)
    - Good for accurate rim/hub simulation
    - Wheel deformation/road contact is challenging

Introduction | Tire Modelling

- Existing Methods
  - Rotating Wall (RW)
    - Easy implementation
    - Too inaccurate (no wall normal velocity)
  - Moving Reference Frame (MRF)
    - Good for tire's grooves
    - Difficult to set up
  - Sliding Mesh (SM)
    - Good for accurate rim/hub simulation
    - Wheel deformation/road contact is challenging

- Combined SM for hubs + automated MRF for treads
  - MRFg (Hobeika & Sebben)
- Generalized moving Reference Frame (GRF)
  - Rotation approximation
  - Good for tire's grooves
  - Non circular patches
  - Automated frame selection

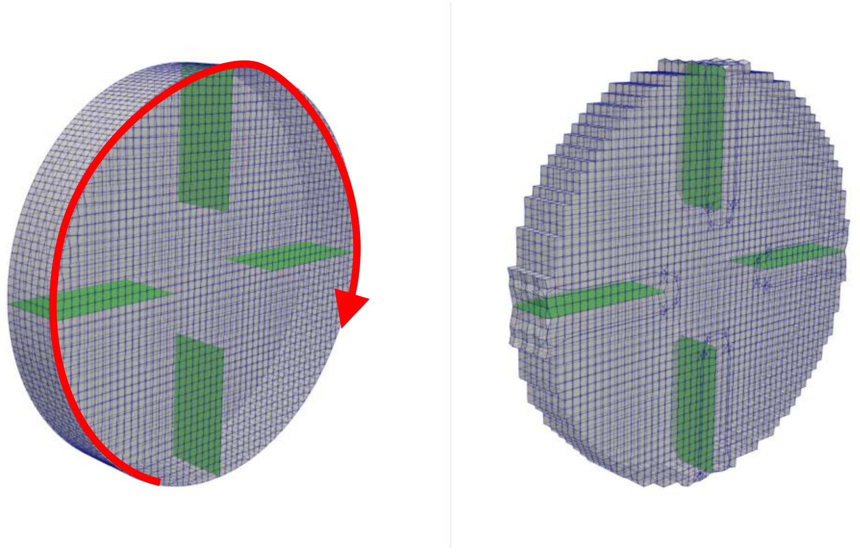
T. Hobeika and S. Sebben, "CFD investigation on wheel rotation modelling," Journal of Wind Engineering and Industrial Aerodynamics, vol. 174, pp. 241–251, Mar. 2018.

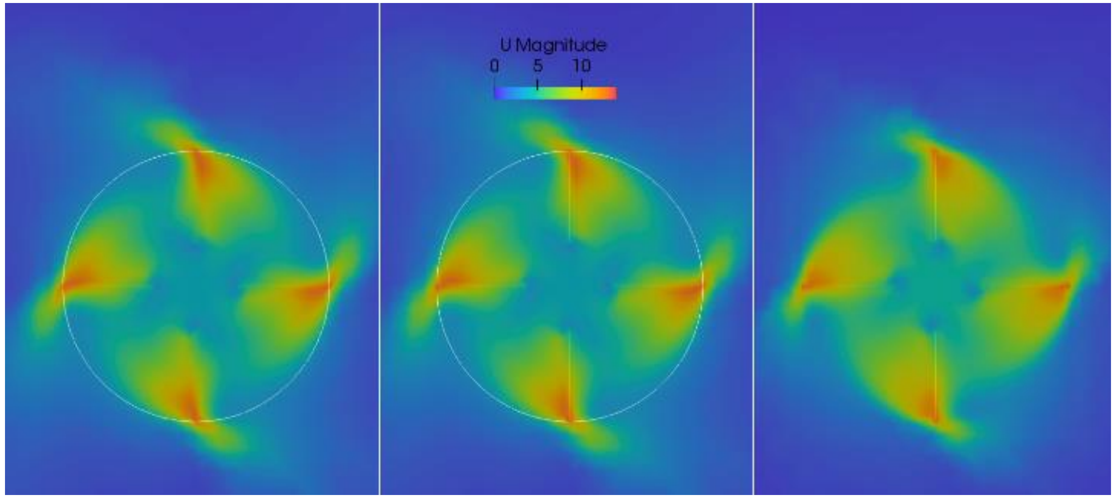
GRF Methodology

GRF Verification

- MRF vs GRF
- $\omega = 90\, rad/s$
- circular vs non-circular zone boundary

Method	Ventilation Moment (Nm)	Iterations
MRF	0.167	1866
GRF (s)	0.166	1761
GRF non-circular (n)	0.163	1243



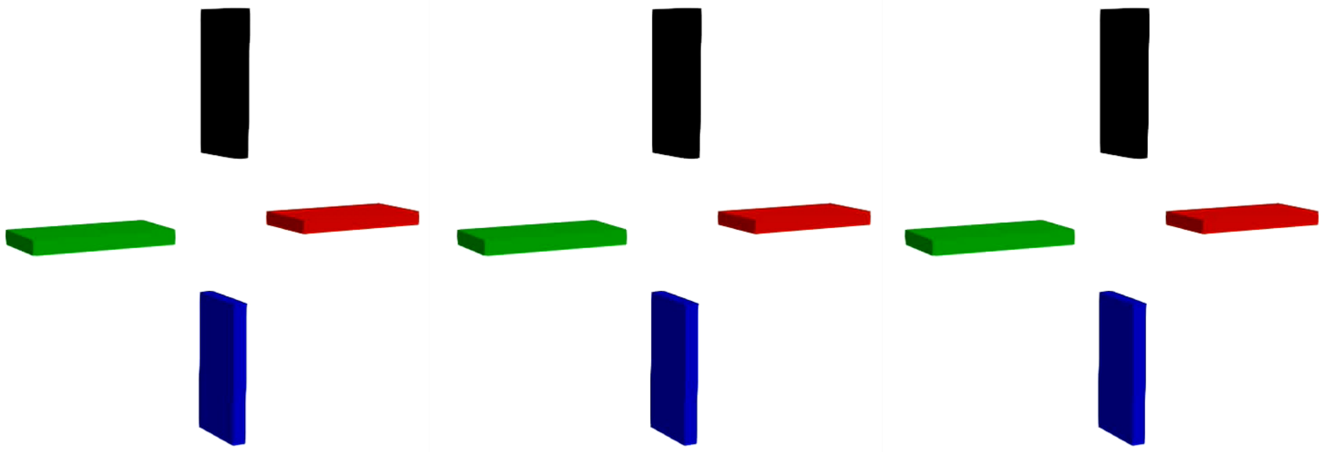


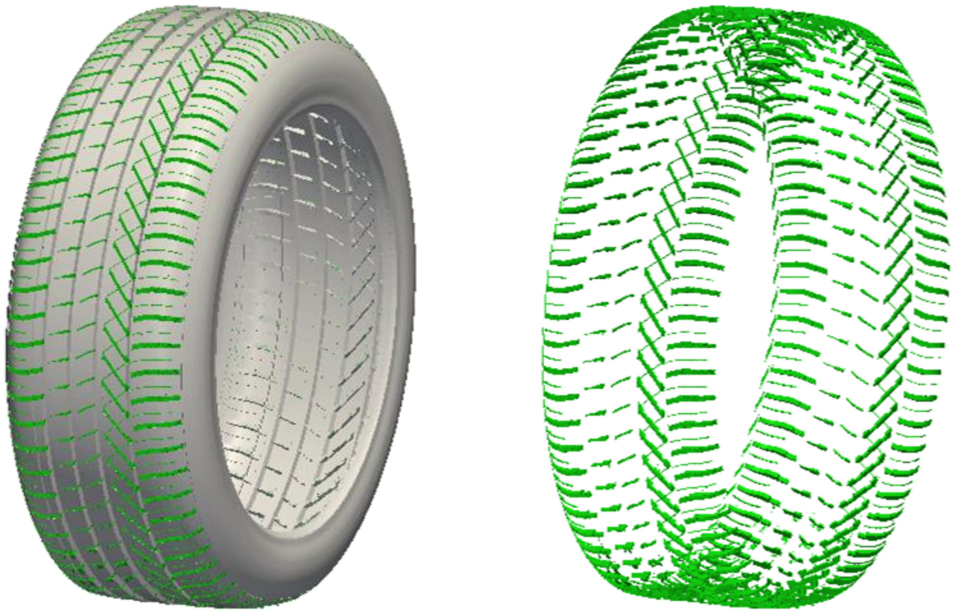
MRF GRF (s) GRF (n)

GRF Methodology

Swept Cell Method

- Complex geometries make frame definitions difficult
- Automated detection
  - Convection equation is solved
  - $\nabla \cdot (\Phi_{\Omega}\tau) = 0$
  - Tracer field indicates zone
- Enabled by GRF support for non-circular frame boundaries
- Remove need for mesh-zone

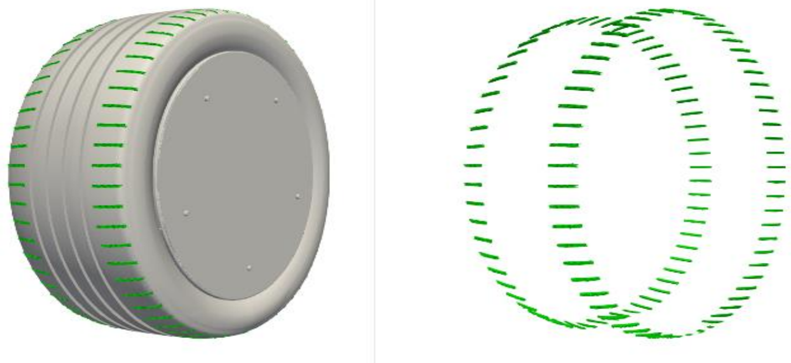




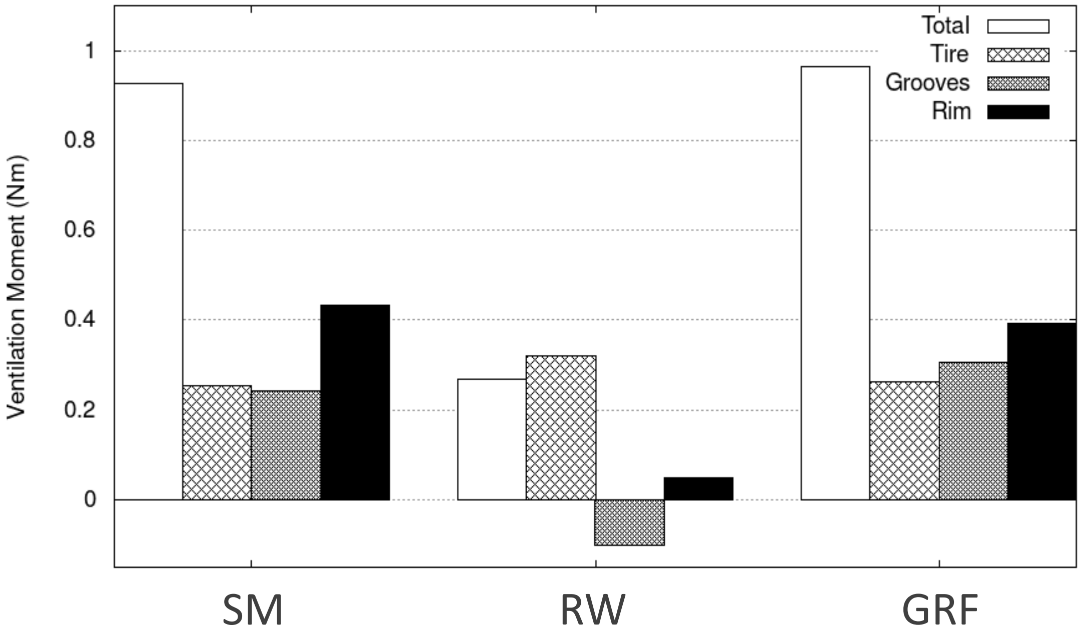
Tire Modelling Results

Stand-alone wheel validation

- uRANS with k-OmegaSST
- ~7 million cells, 2mm surface face size
- 3 Configurations:
  - SM on the whole wheel
  - RW on the whole wheel
  - GRF on the grooves + SM for on the rim
- Similar ventilation moment prediction between SM and GRF



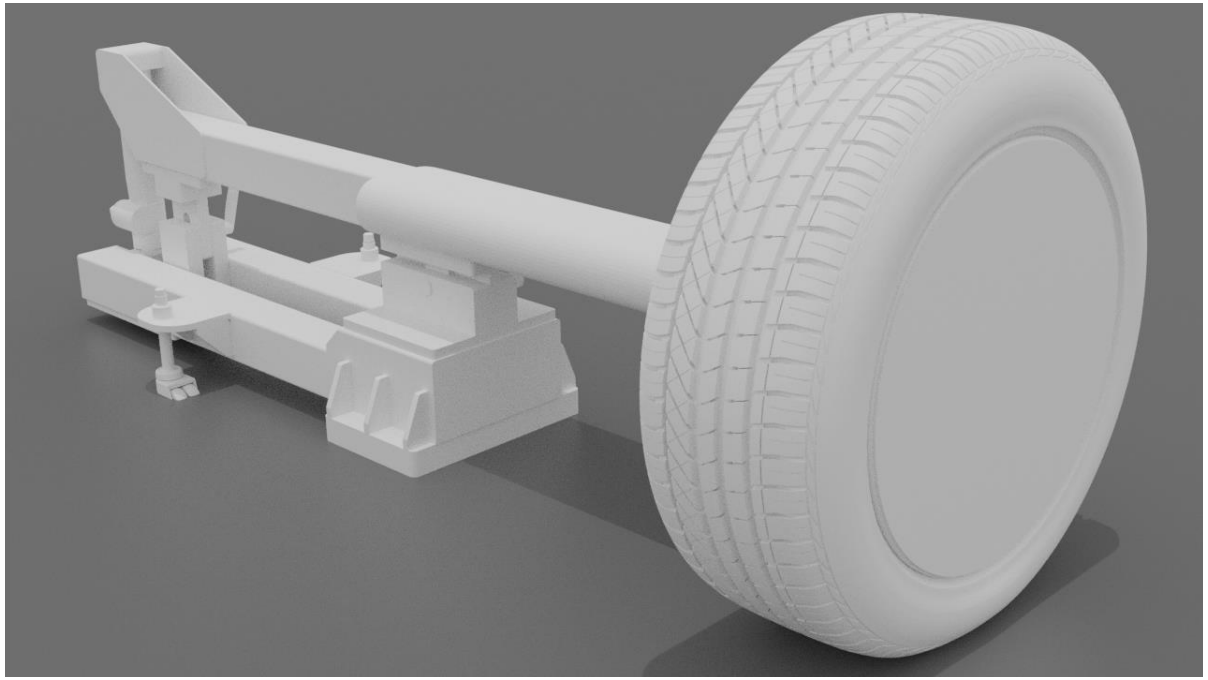
GRF zone automatically created with swept cell method



Ventilation moments for three different configurations.

Tire Modelling Results

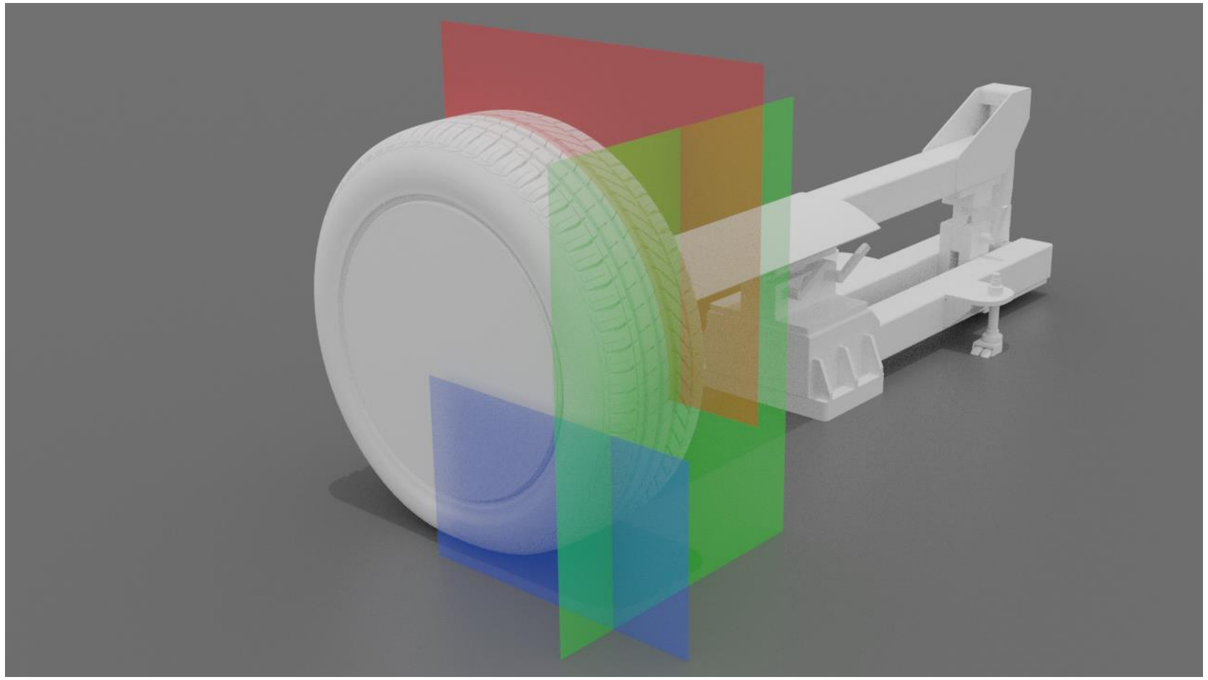
- With kind permission of BMW AG
- PhD thesis
  - Schnepf, B., „Untersuchung von Einflussfaktoren auf die Umströmung eines Pkw-Rades in Simulation und Experiment“, Dissertation, Technische Universität München, 2016
- Windtunnel campaign with moving ground at 140 km/h.
- Deformed tire



engys®

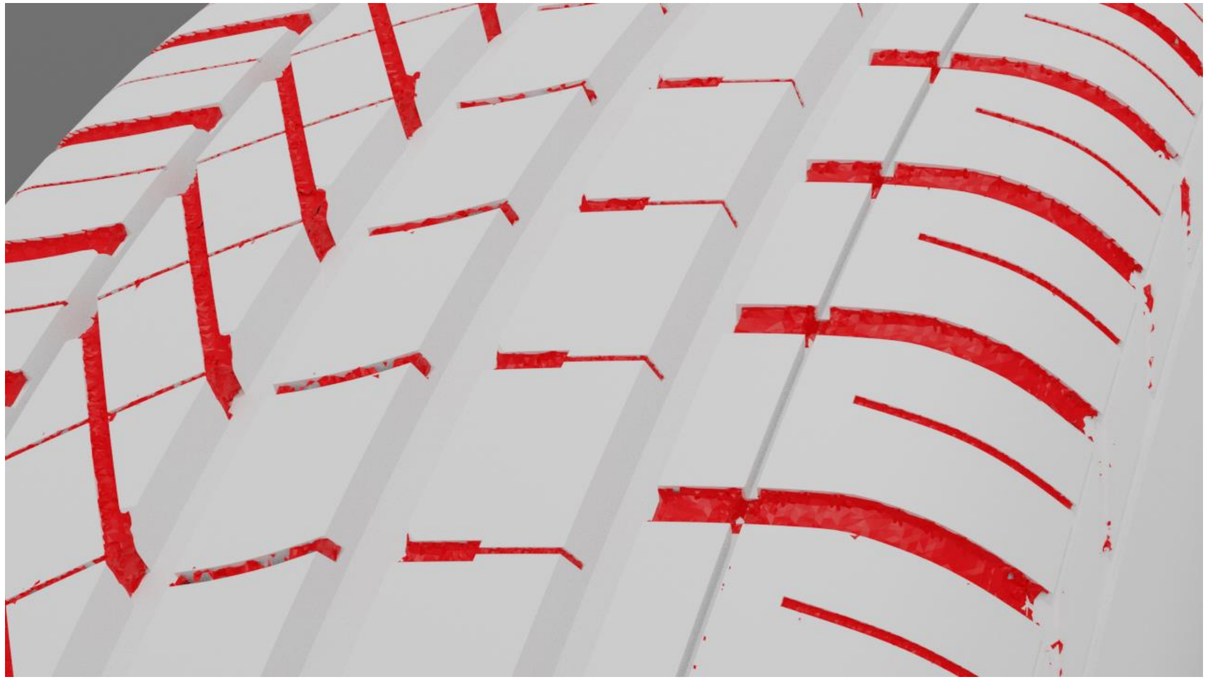
Tire Modelling Results

- Experimental data available
- Pressure and velocity measurements in various planes

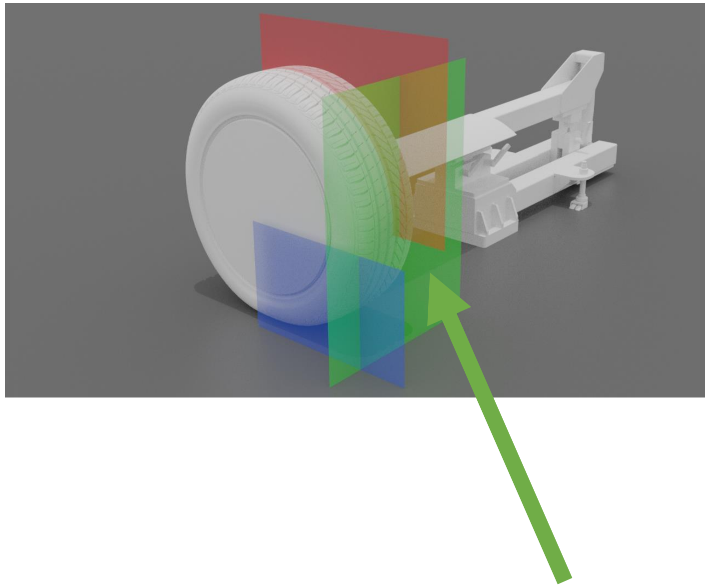


Tire Modelling Results

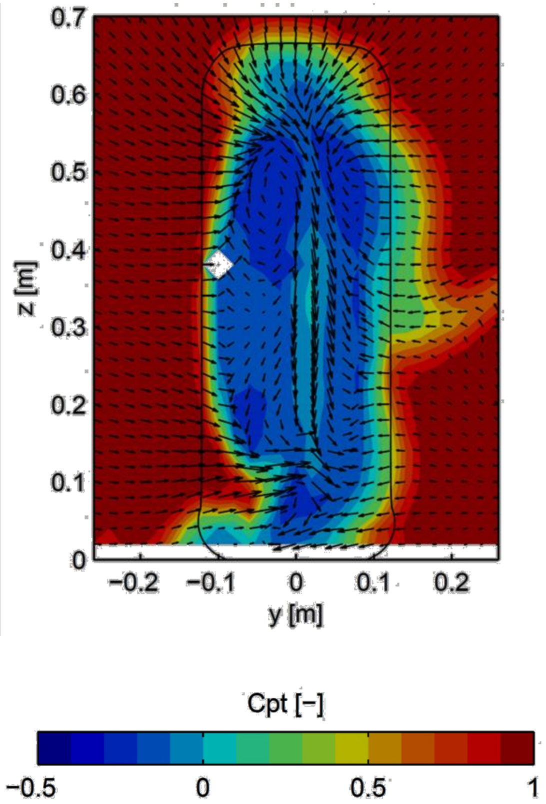
- Automatic GRF cells selection with sweep method

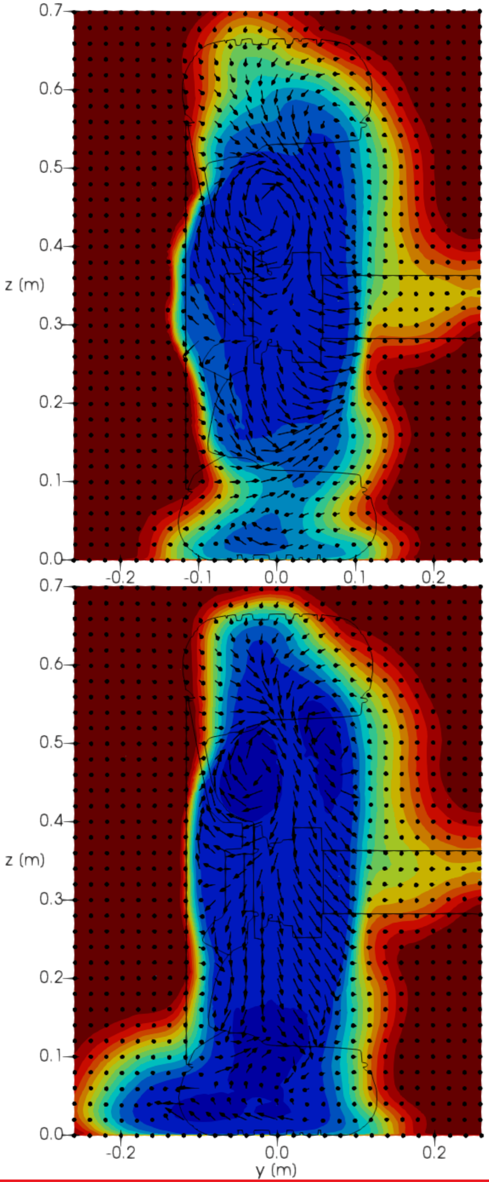


Tire Modelling Results



Experiment

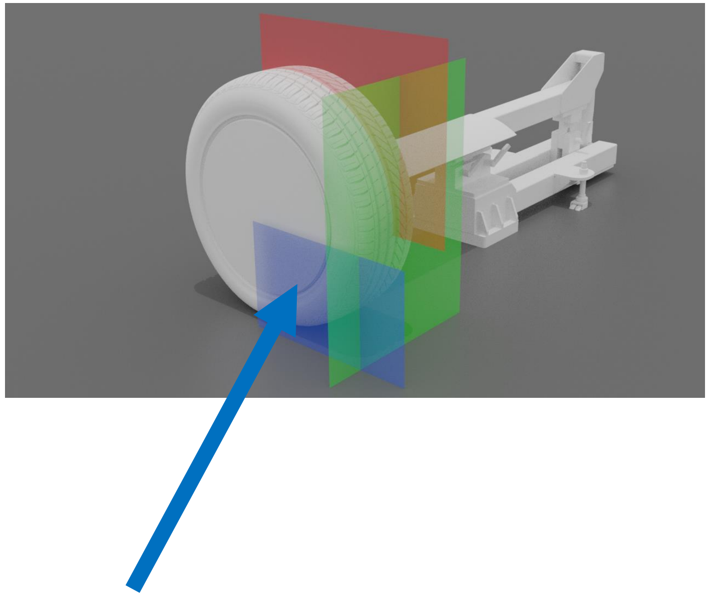




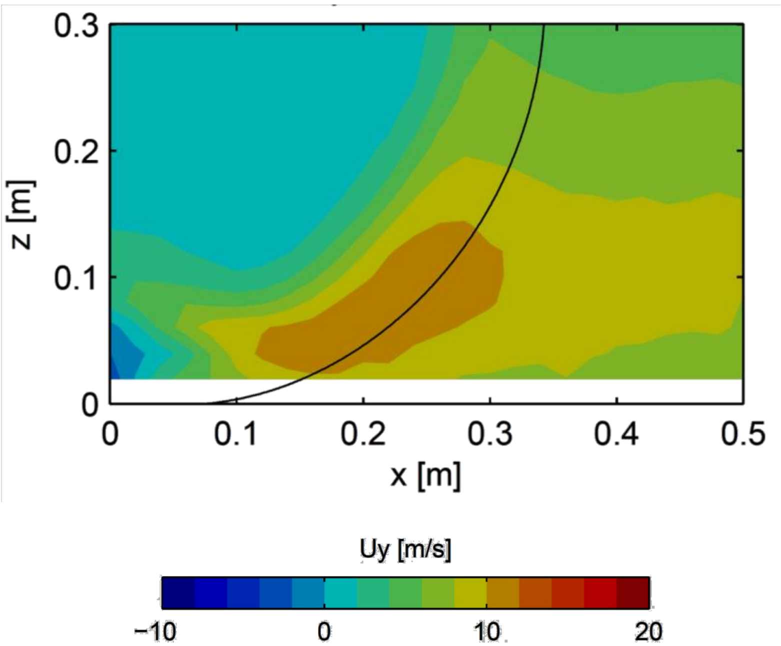
GRF

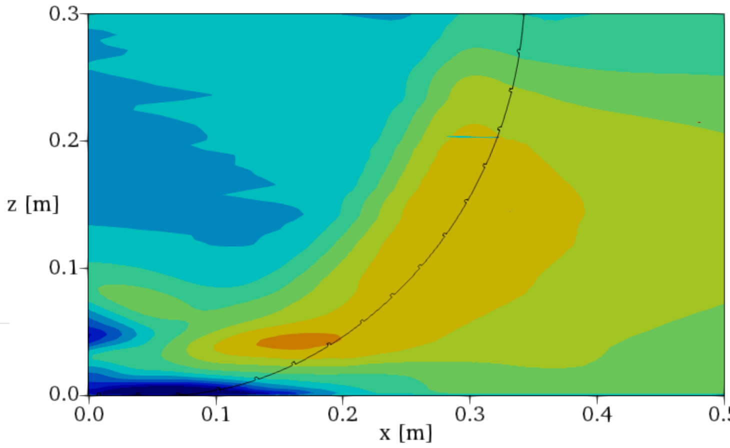
Rot Wall

Tire Modelling Results

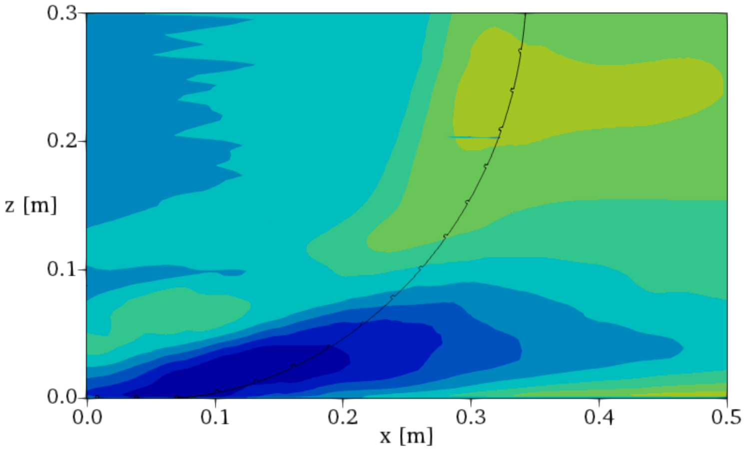


Experiment





GRF



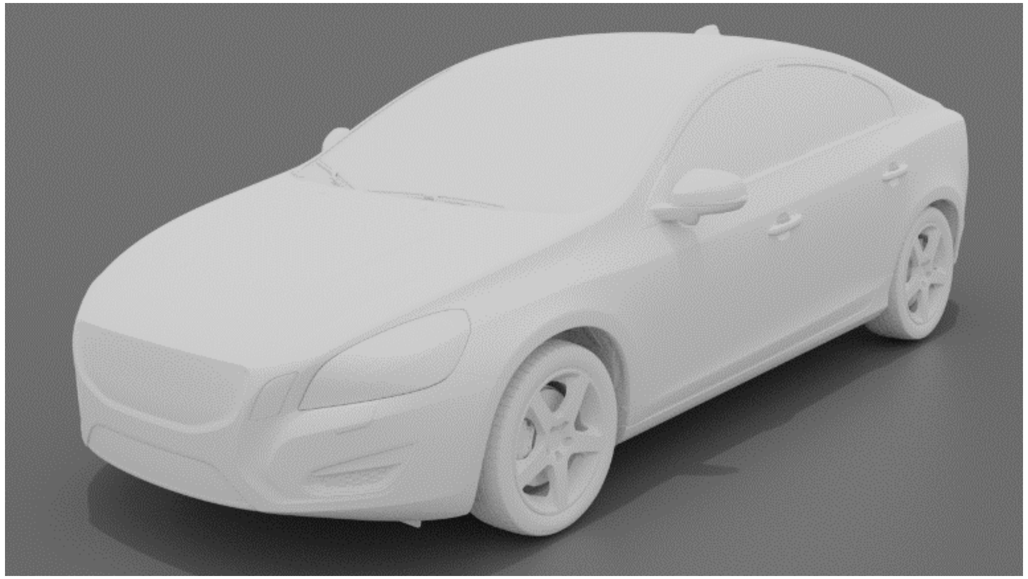
Rot Wall

Tire Modelling Results

Full car simulation

- With kind permission of Volvo Cars
- Volvo S60
- Open and Closed Rim configurations
  - SM used for Open Rim
- Difference in drag coefficient between slick and detailed tires
- Compare with experimental values for

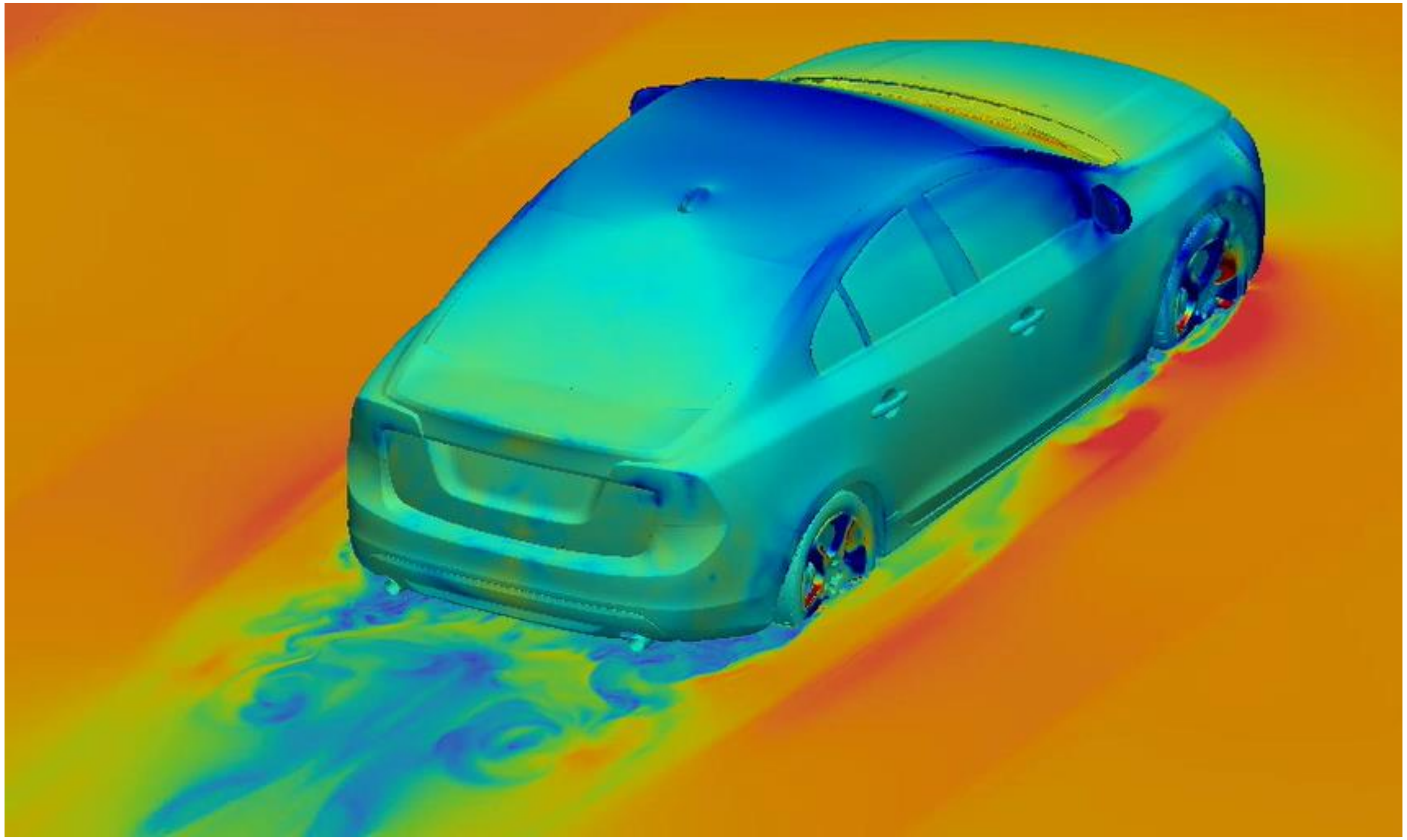
$$\Delta C_D = C_{D\ Detail} - C_{D\ Slick}$$



Tire Modelling Results

Full car simulation

- Delayed Detached Eddy Simulation (DDES) Spalart-Allmaras turbulence model
- ~100 million cells
- Inlet velocity: 100 Km/h
- Average over 1 second

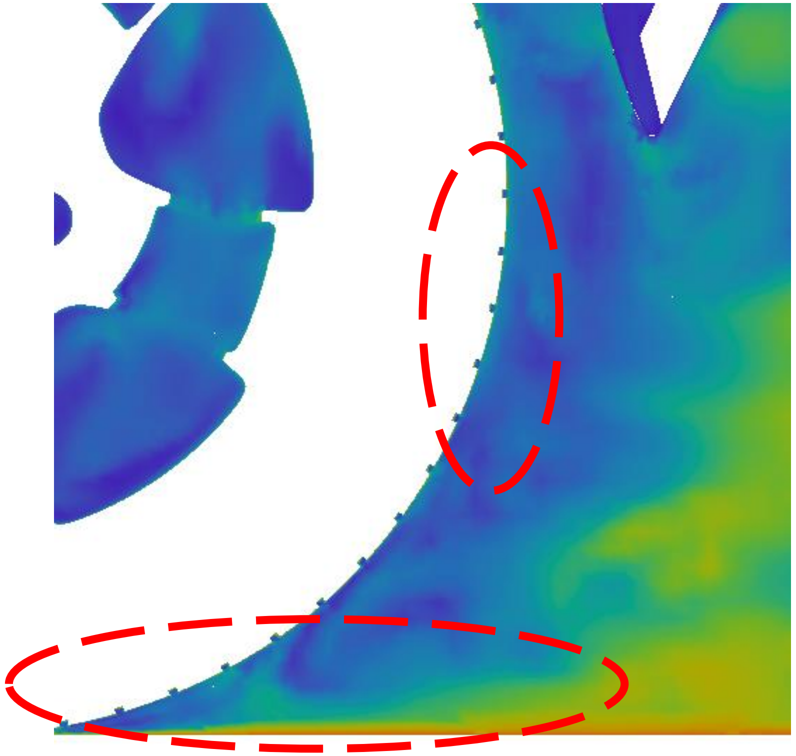


engys®

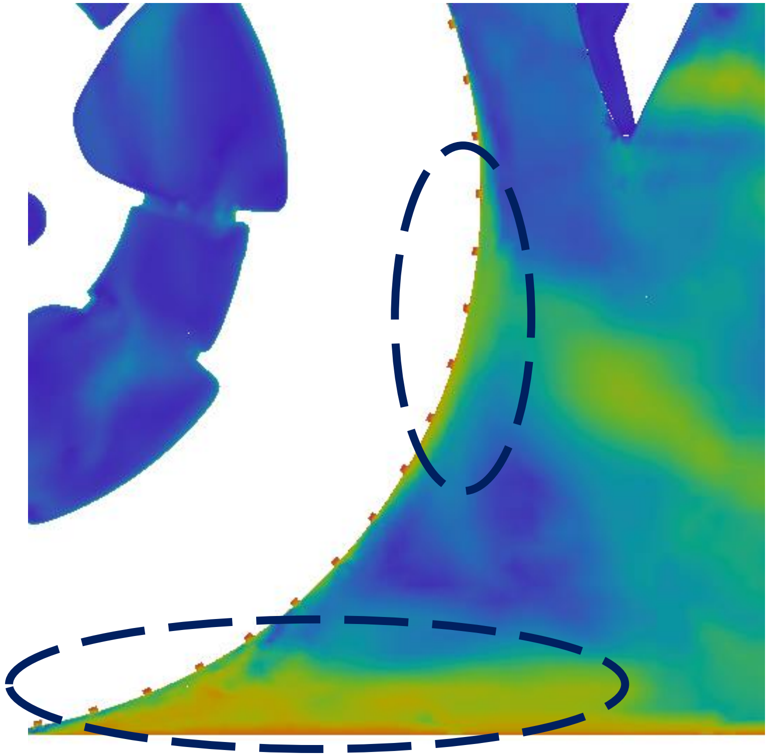
Tire Modelling Results

Full car simulation

- Slice across the wheel plane
- Difference in the velocity field in the vicinity of the grooves



Rotating Wall

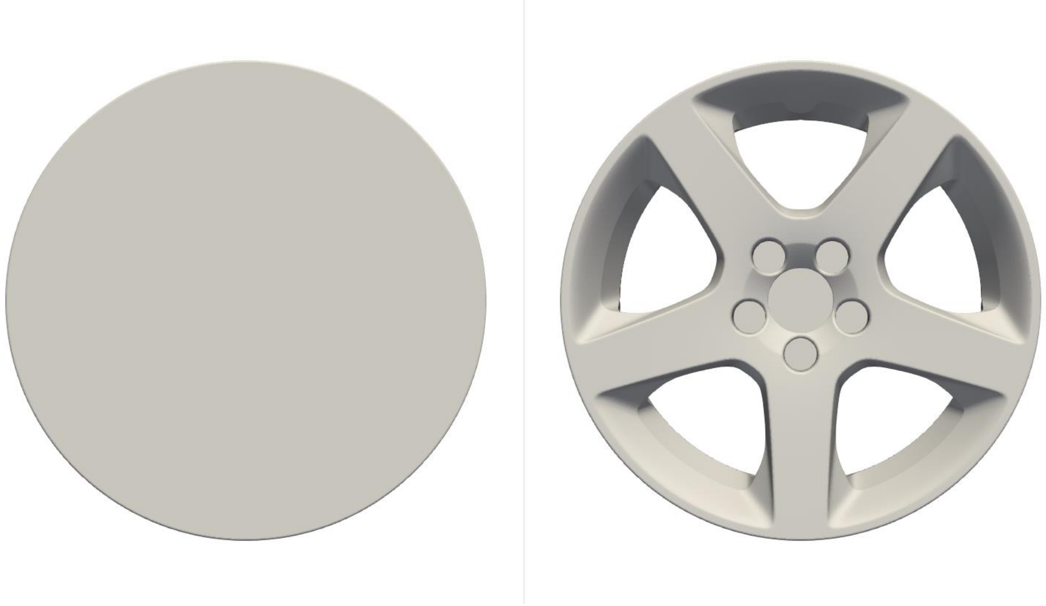


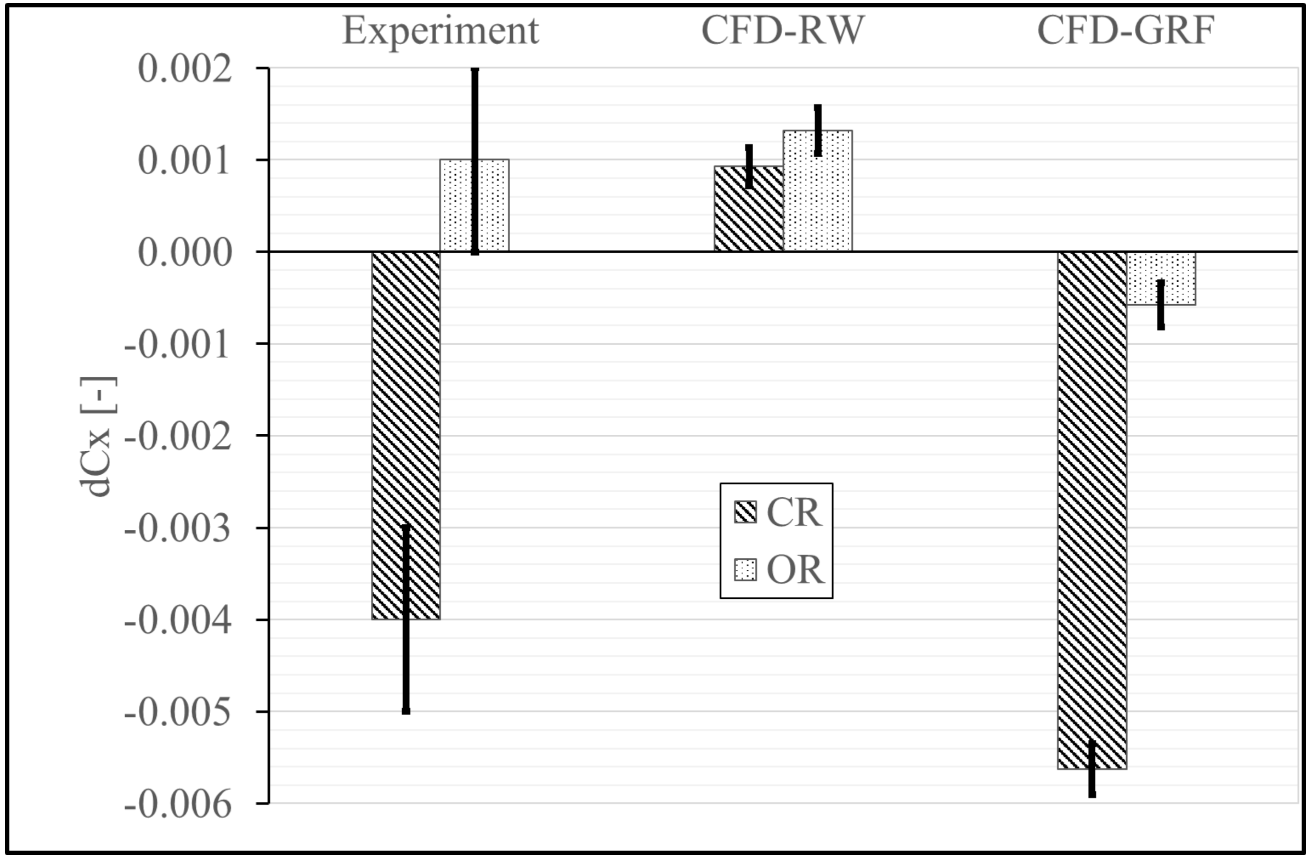
GRF

Tire Modelling Results

Full car simulation

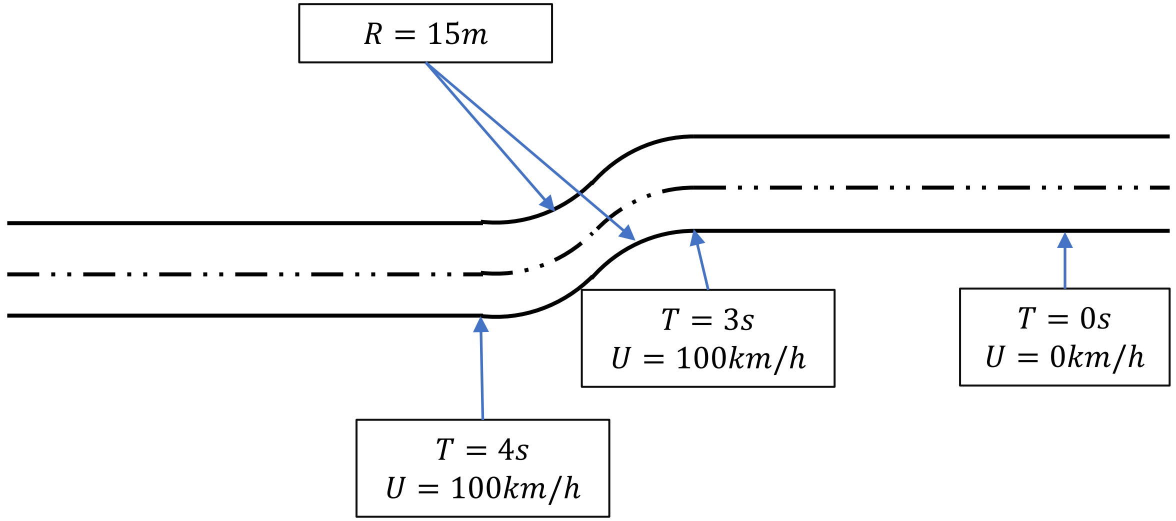
- Comparison of ΔC_D
- Good prediction for closed rims
- Ambiguous results for open rims



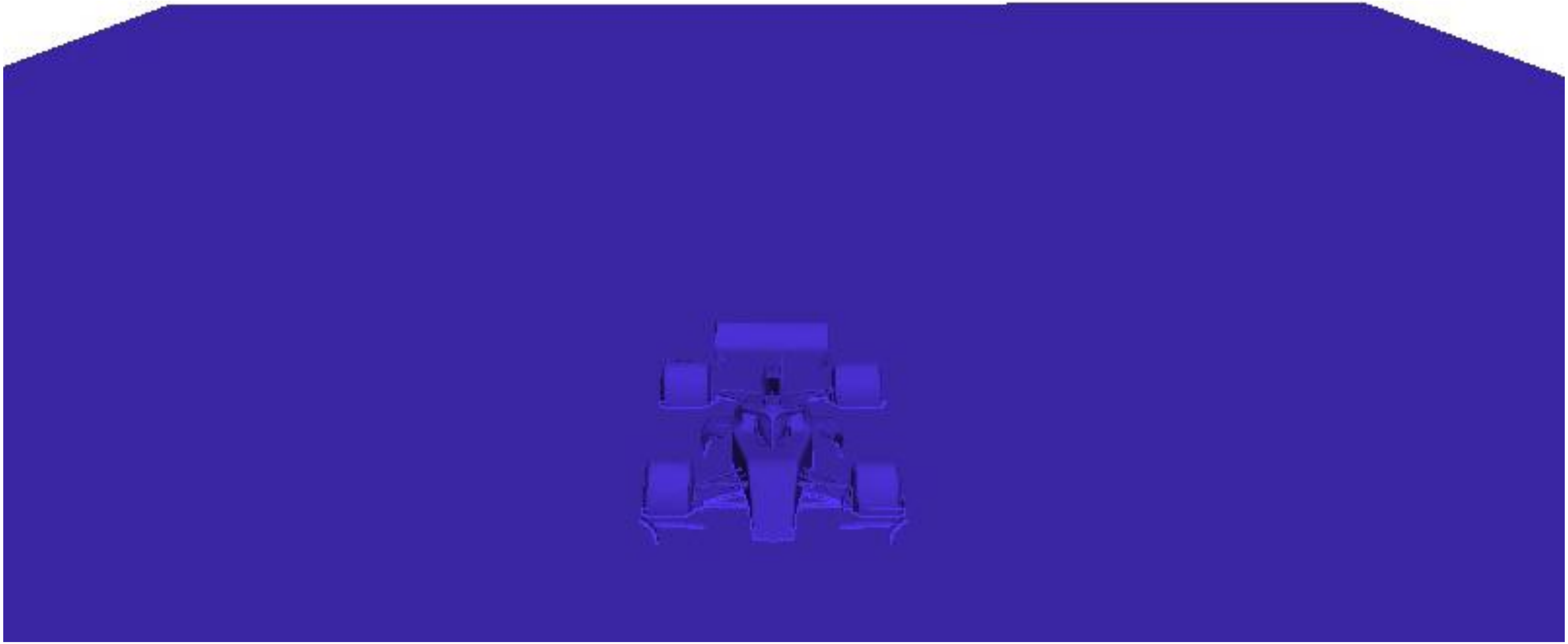


Extended Reference Frames | Application

- Vehicle cornering through a chicane
- Vehicle max speed 100km/h



Extended Reference Frames | Application



Conclusions

- For wheel modelling
  - Easy to set up and use
  - Accurate
  - GRF can support any shape and any motion
- For vehicle cornering
  - Globalized definition of reference frames
  - Nested frames support
- Future work:
  - sliding mesh interface automation
  - performance optimization
  - Extended reference frames for dynamic meshes
  - GUI support

Disclaimer

ENGYS Limited is the proprietor of the copyright subsisting in this work. No part of this work may be translated, reprinted or reproduced or utilised in any material form either in whole or in part or by any electronic, mechanical or other means, now known or invented in the future, including photocopying and recording, or in any information storage and retrieval system, without prior written permission from ENGYS Limited.

Applications for permission to reproduce any part of this work should be addressed to ENGYS Limited at info@engys.com