



Investigation on the impact of a cracked rear axle tie rod on component, semi-axle and full vehicle level

ECS Simulation Conference

Speaker

Robert Schurmann – Volkswagen AG

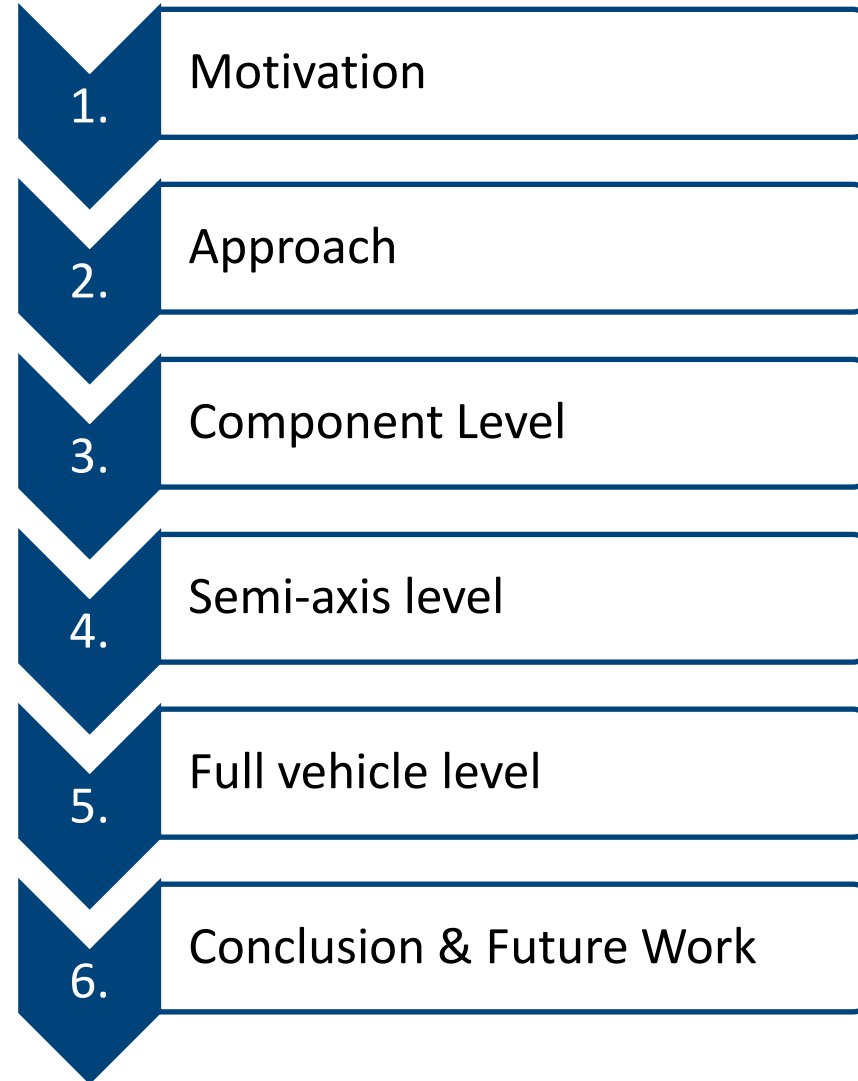
Co-Authors:

Alexander Krause, Dr. Jan Frischkorn – Volkswagen AG

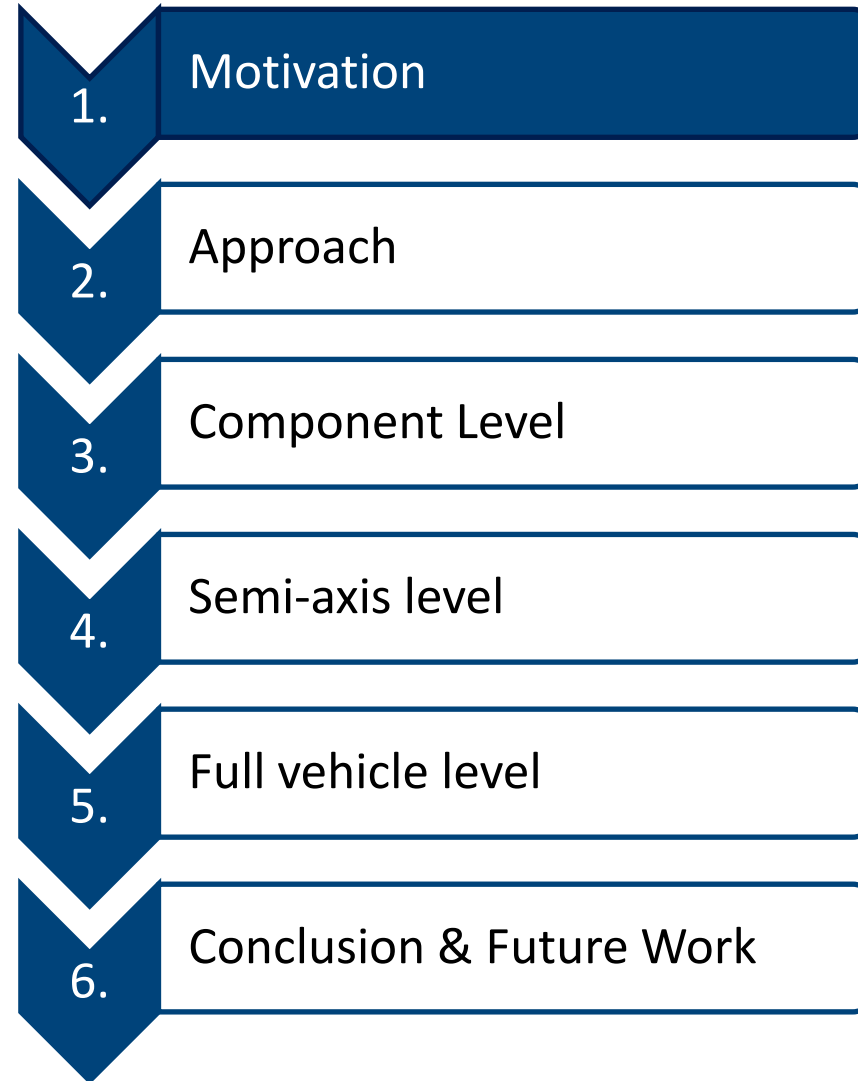
Prof. Alexander Lion – Universität der Bundeswehr München

Linz | May 10, 2023

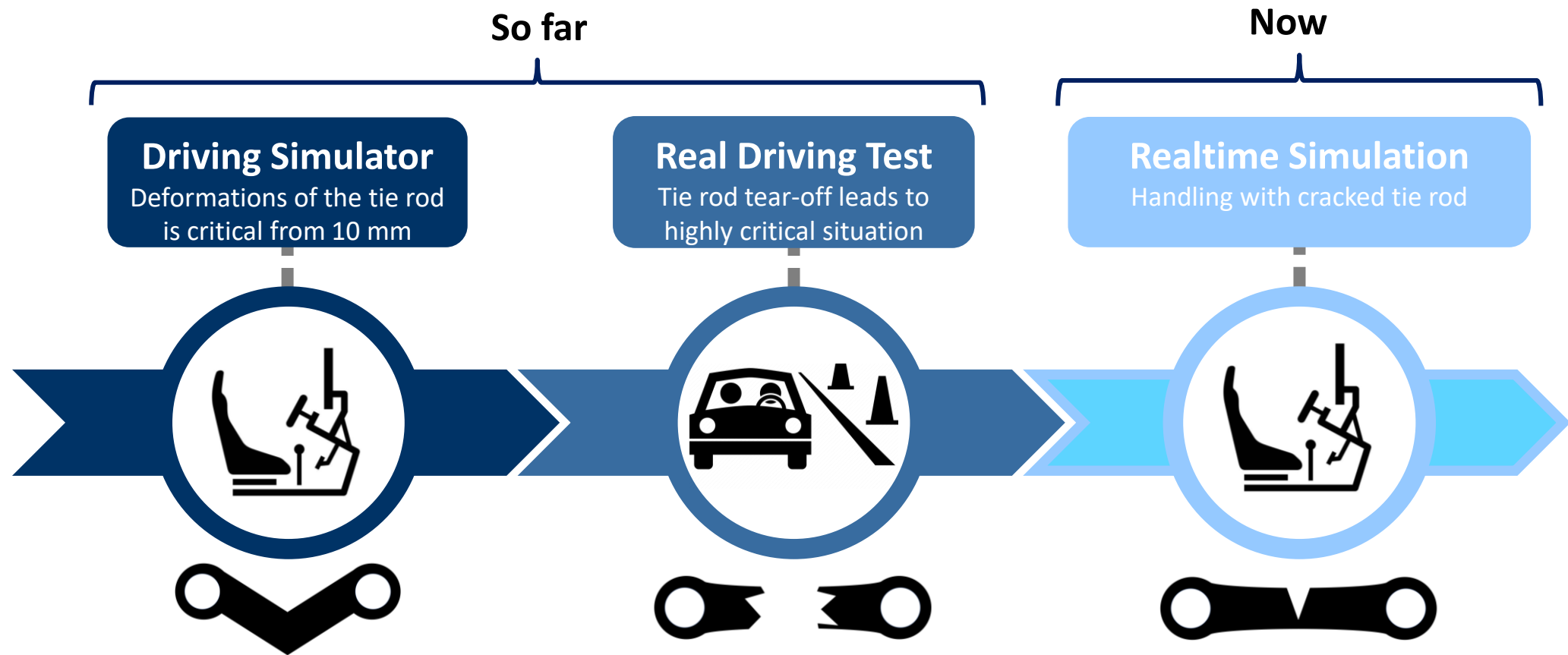
Agenda



Agenda

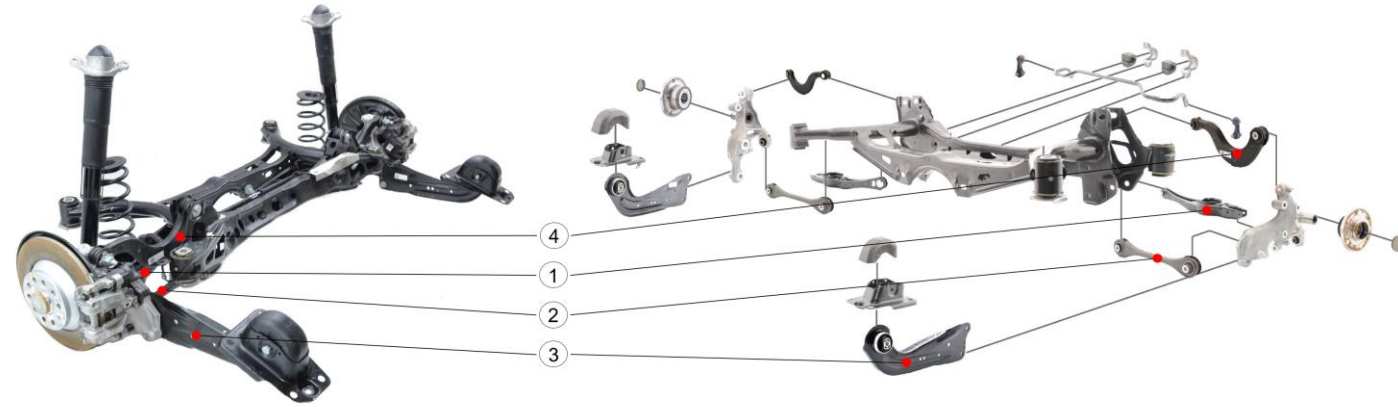
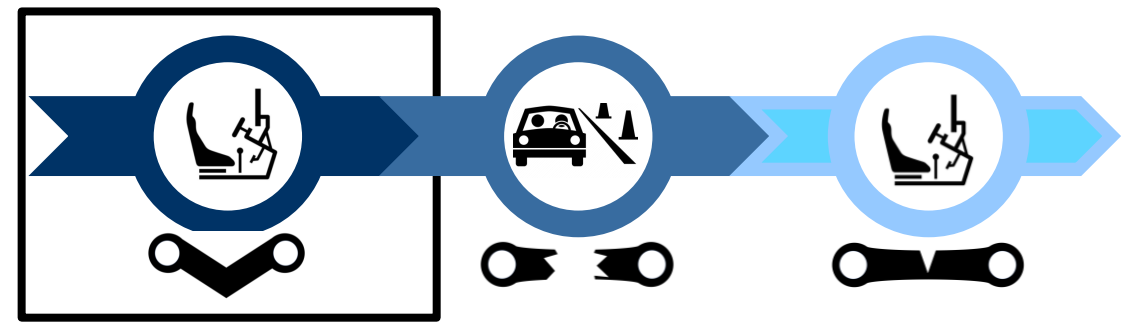


Motivation



Motivation:
Subjective assessment of a vehicle with a cracked axle component in the dynamic driving simulator.

Motivation



1 - Spring Link 2 - Tie Rod 3 - Trailing Arm 4 - Upper Control Arm

- **Investigations on the controllability of deformed axle components:**
 - Development of a process chain for the transfer of MBS models into real-time capable CarMaker models
 - Study on subjective perceptions of the criticality of deformed axle components in the driving simulator and a validation study
- **Tie Rod and Spring Link are critical components when it comes to driving stability**

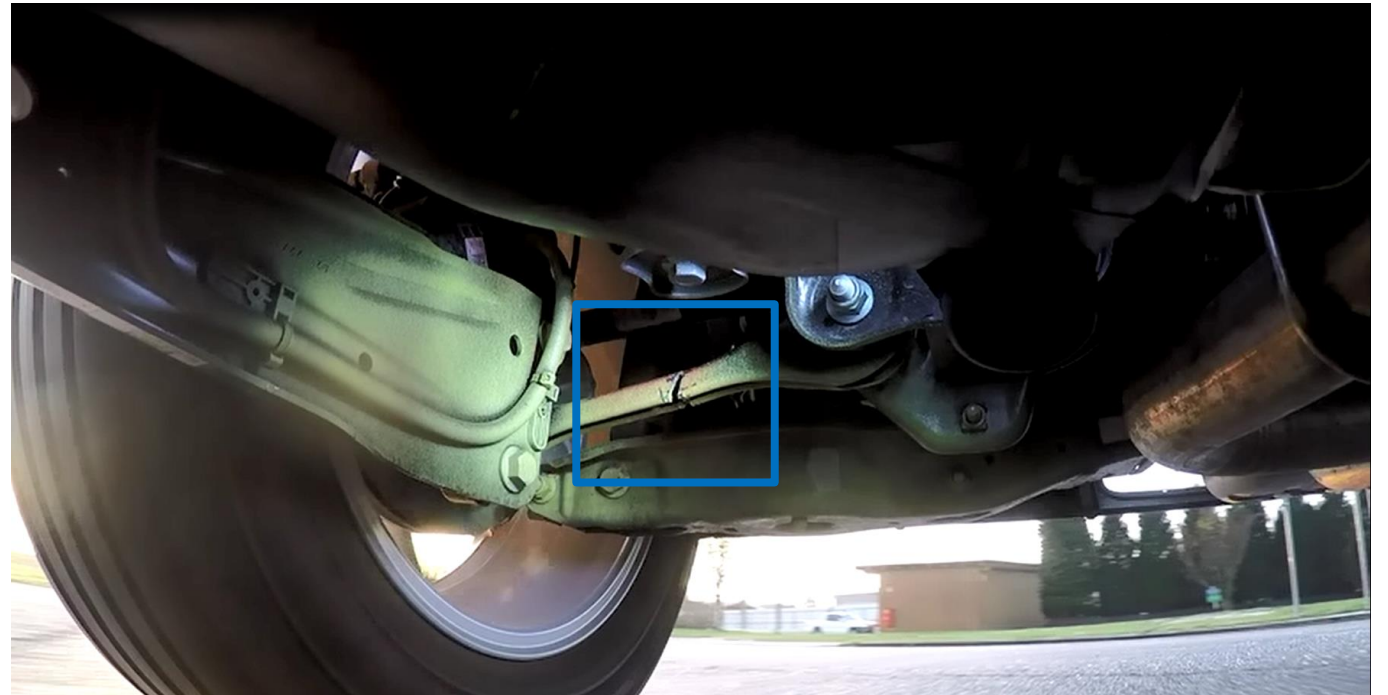
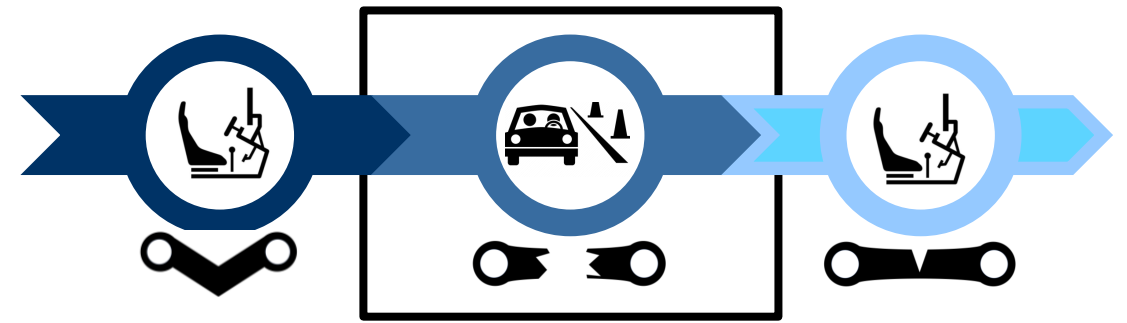
Motivation

- **Real vehicle tests for the tie rod tear-off:**

- Failure of the tie rod is critical and leads to a driving behaviour that is difficult to control
- Spontaneous link failure cannot yet be realized on the driving simulator

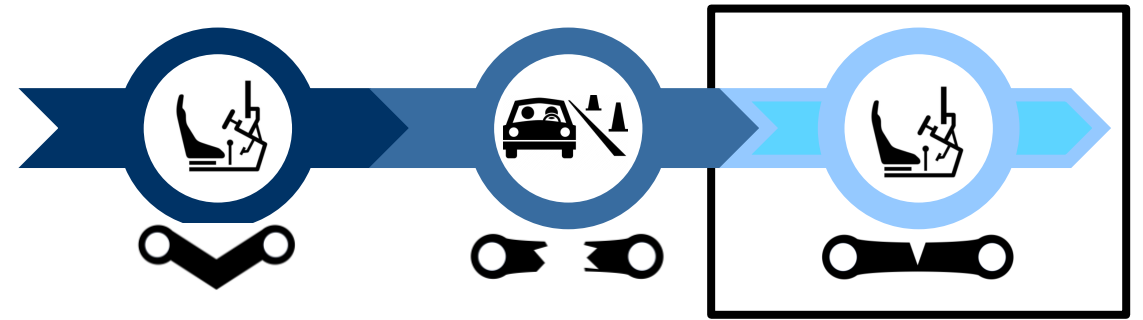
- **Advantages of a driving simulator:**

- ✓ Reduced costs
- ✓ Reduced development time
- ✓ Improved replicability of test cases
- ✓ Lower risk to the test driver



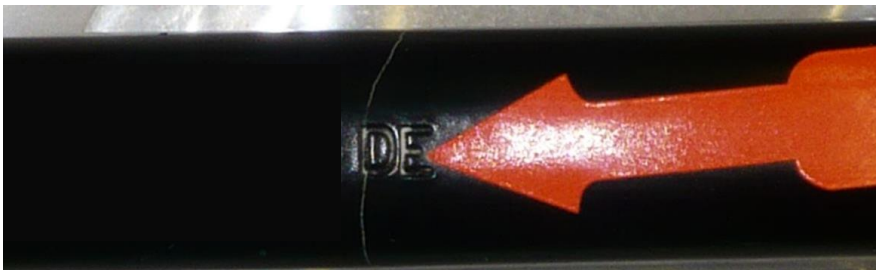
Component was sawn to provoke demolition!

Motivation



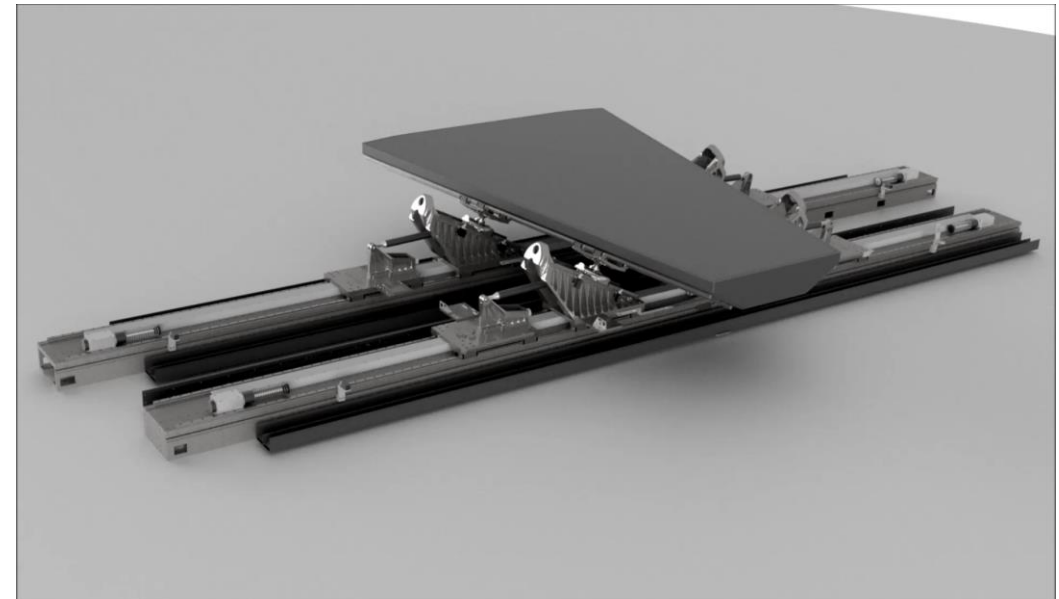
- Cracks can occur for various reasons (accidents, misuse, overload ...)
 - Example:** stamped part number led to cracking (laser engraving is used now)
- Objective:** Development of a process chain in order to subjectively assess the effects of cracked components on the driving behaviour

Cracked Tie Rod

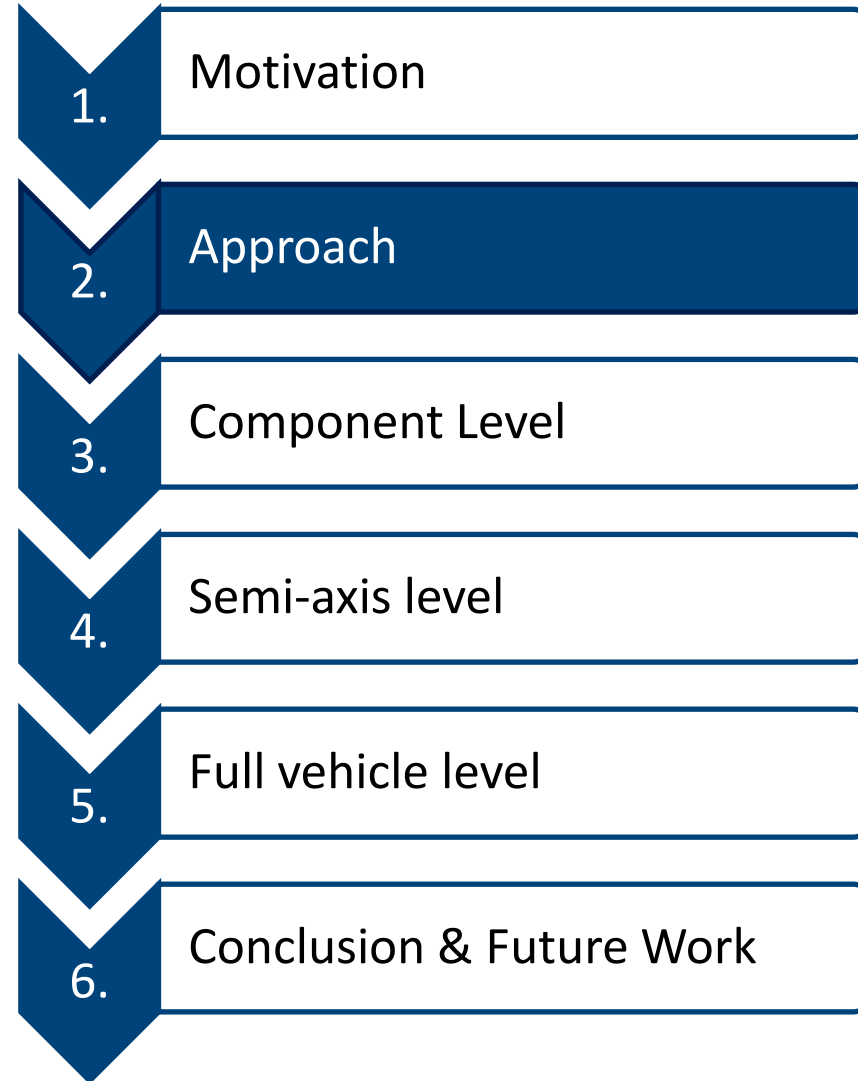


In an early development phase, cracks appeared due to stamped part numbers after fatigue testing. As a result, the metal stamping was replaced by a laser engraving.

Dynamic Driving Simulator (AB Dynamics) at HS Kempten

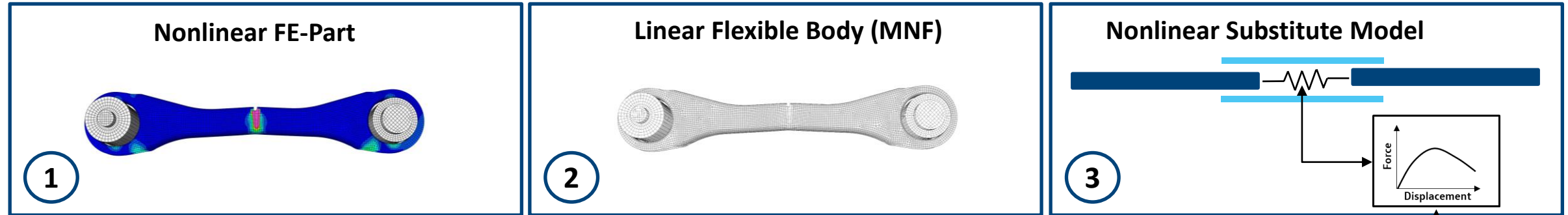


Agenda

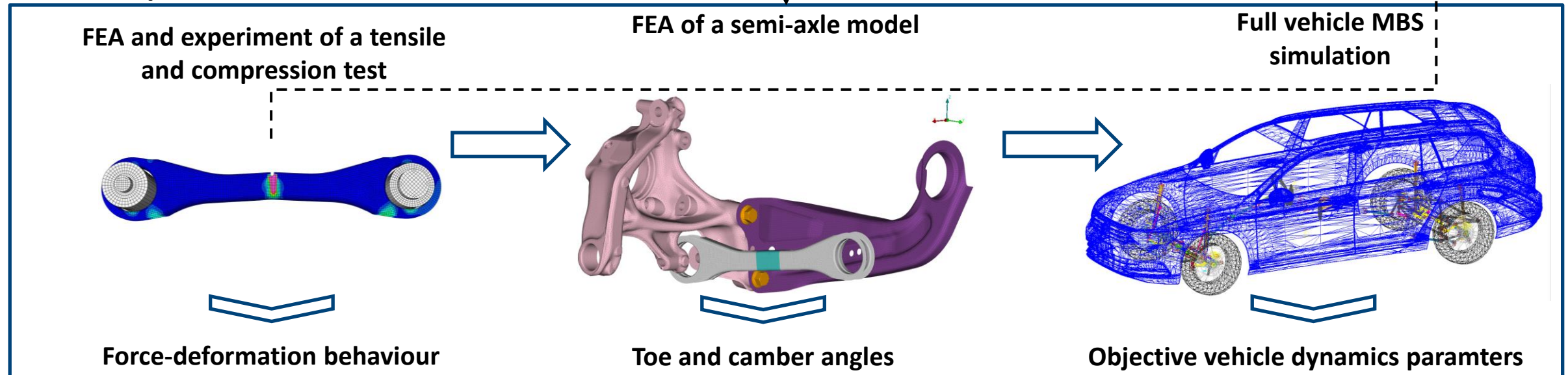


Approach

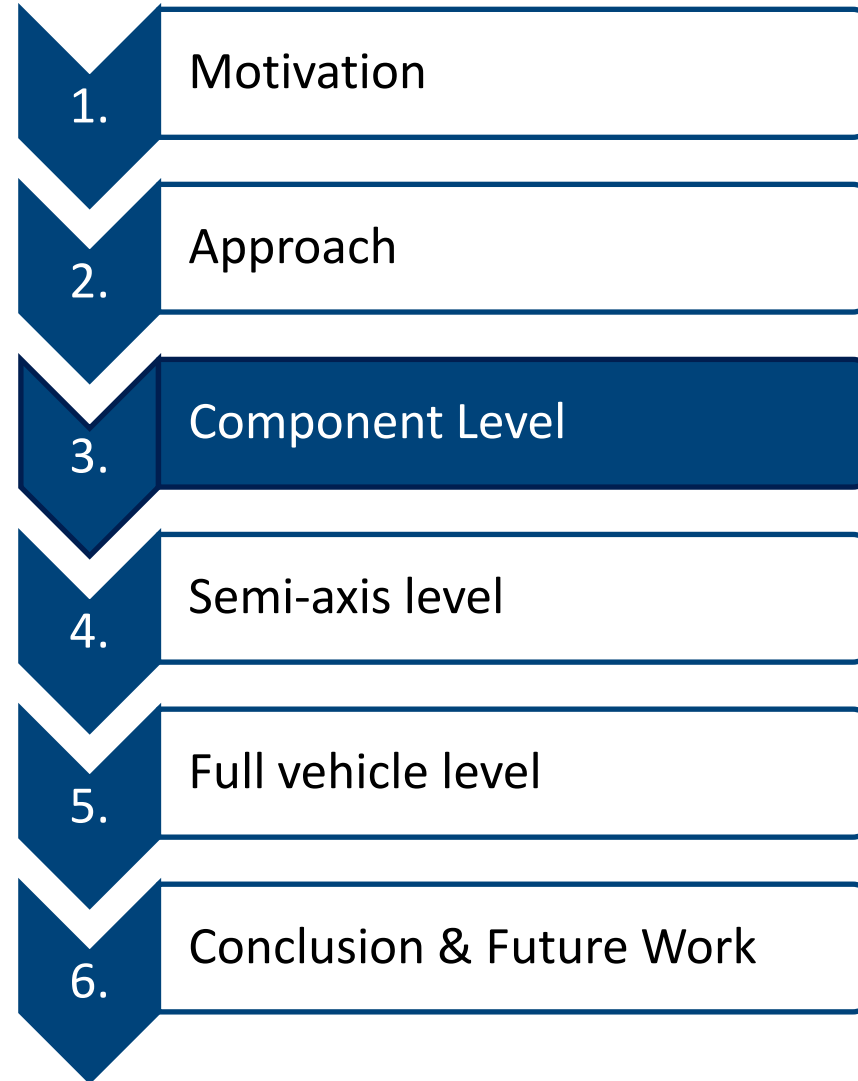
Tie Rod Models



Validation process



Agenda

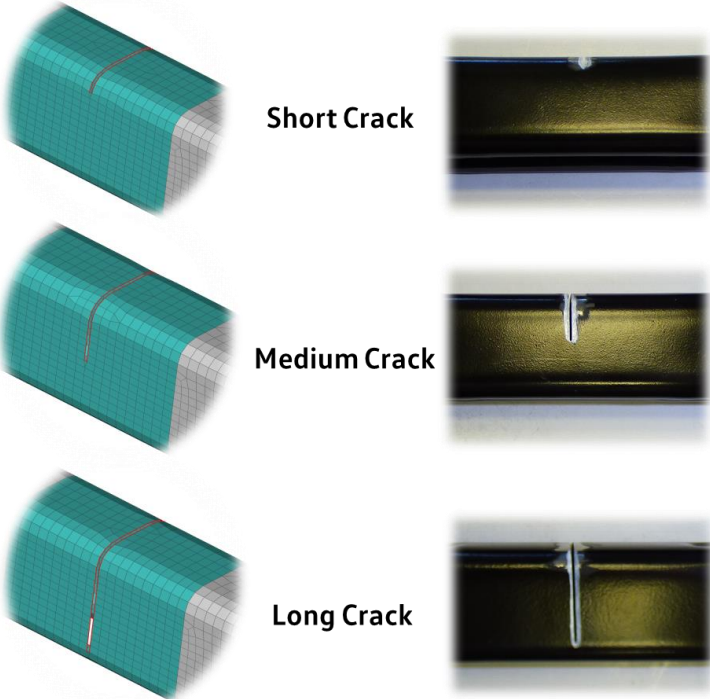
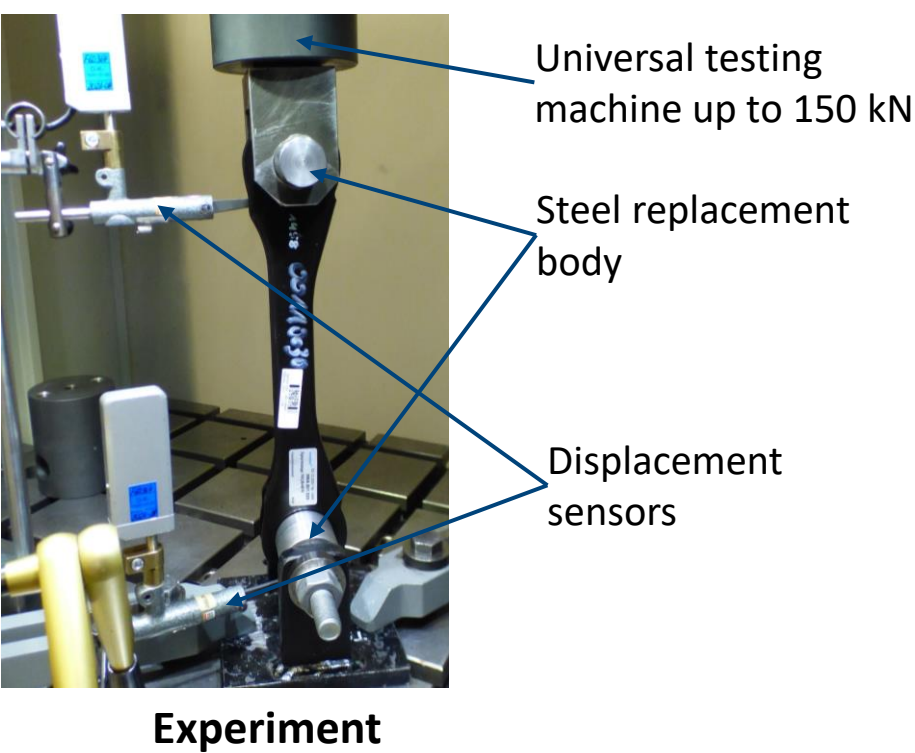
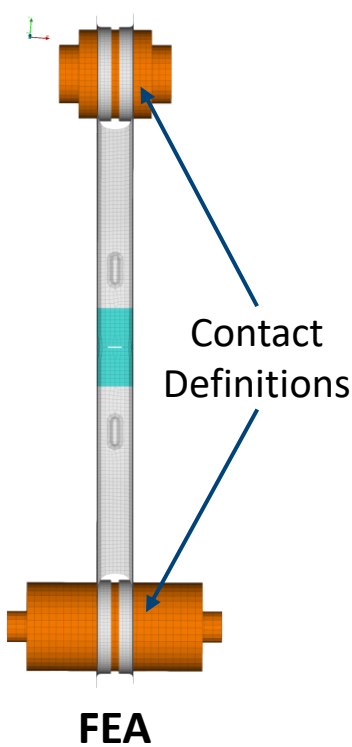
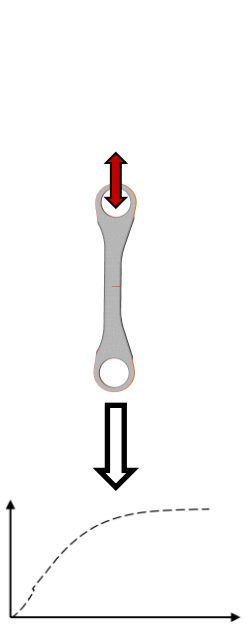


Component level



- Force-deformation curve by quasi-stationary tensile and compression test:
 - Investigation of component stiffness depending on the crack length
 - Comparison of FEA and experiment

Crack length	Existing cross-sectional area
Short	70 %
Medium	45 %
Long	20 %

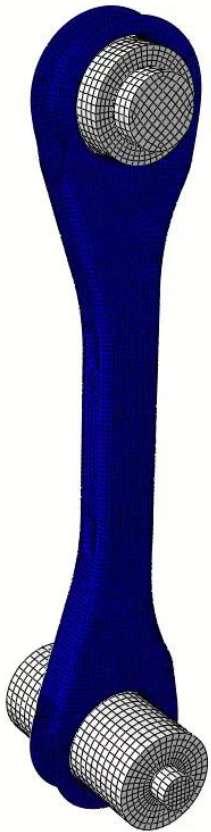


Component level

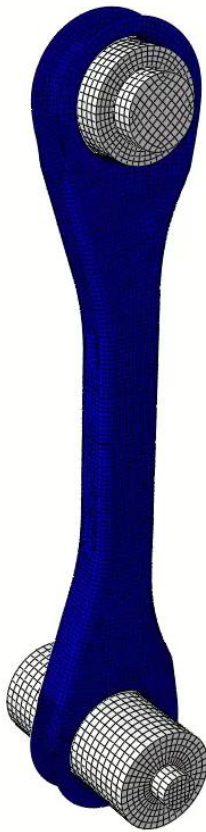


Tensile Test

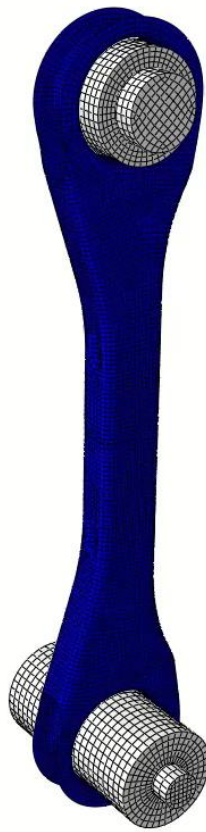
Crack-free



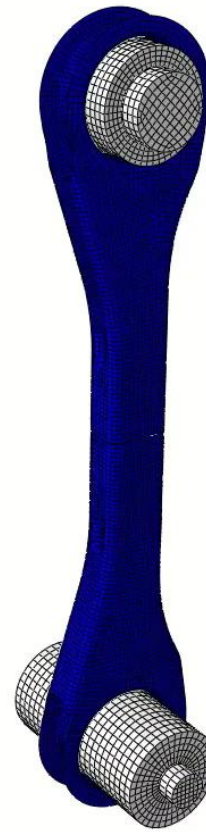
Short Crack



Medium Crack

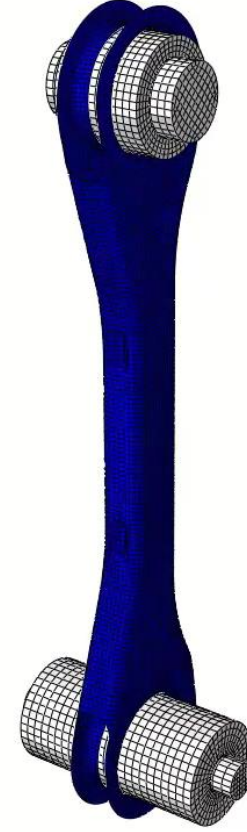


Long Crack

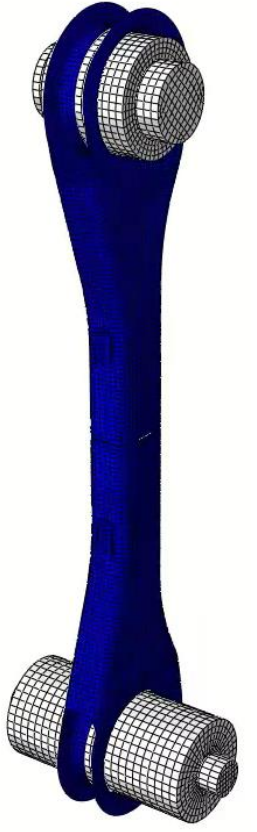


Compression Test

Crack-free



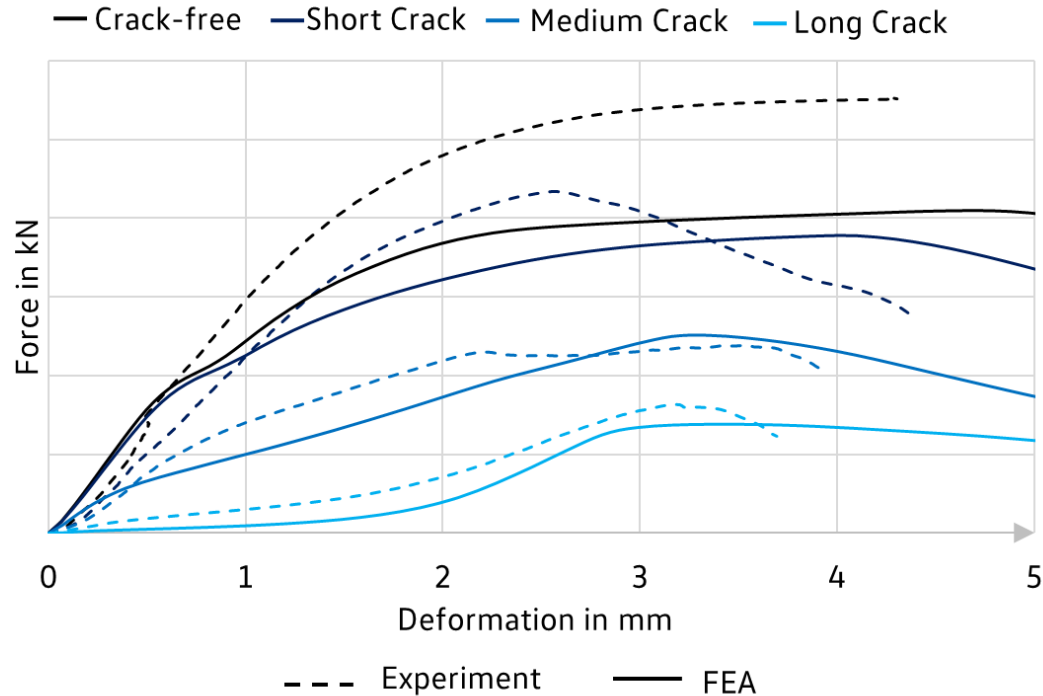
Long Crack



Component level



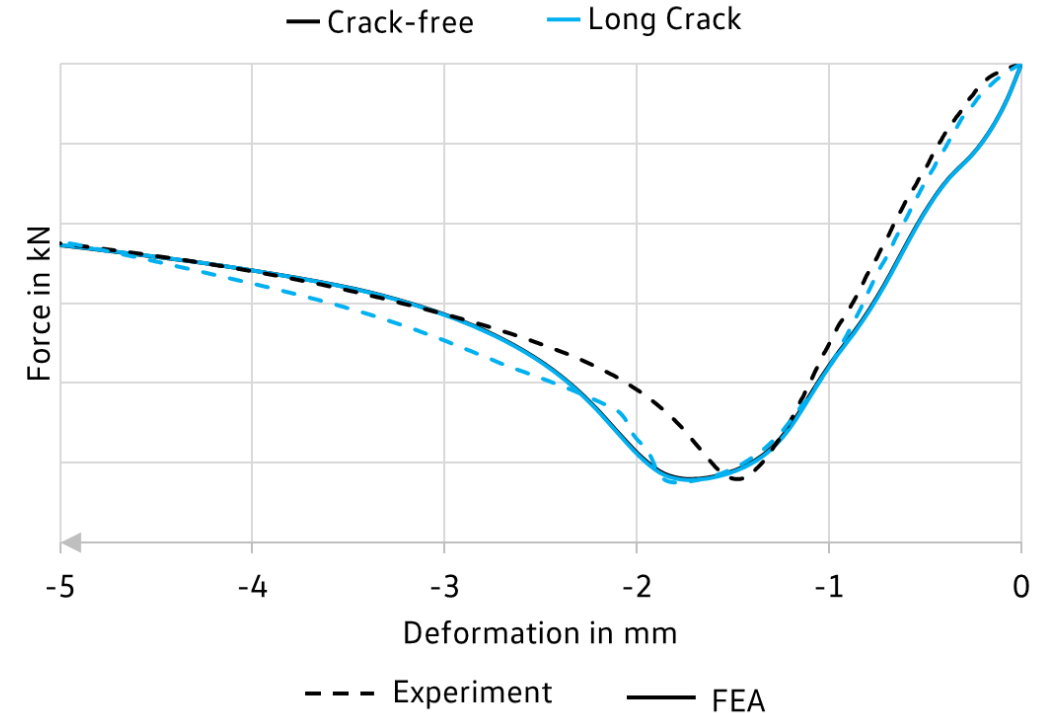
Tensile Test



- Differences decrease with increasing crack length
- Simulation plasticises earlier (strain hardening is not considered)
- With increasing crack length, the bending components increase and the slope at the origin decreases

→ Component stiffness is reduced by the cracks

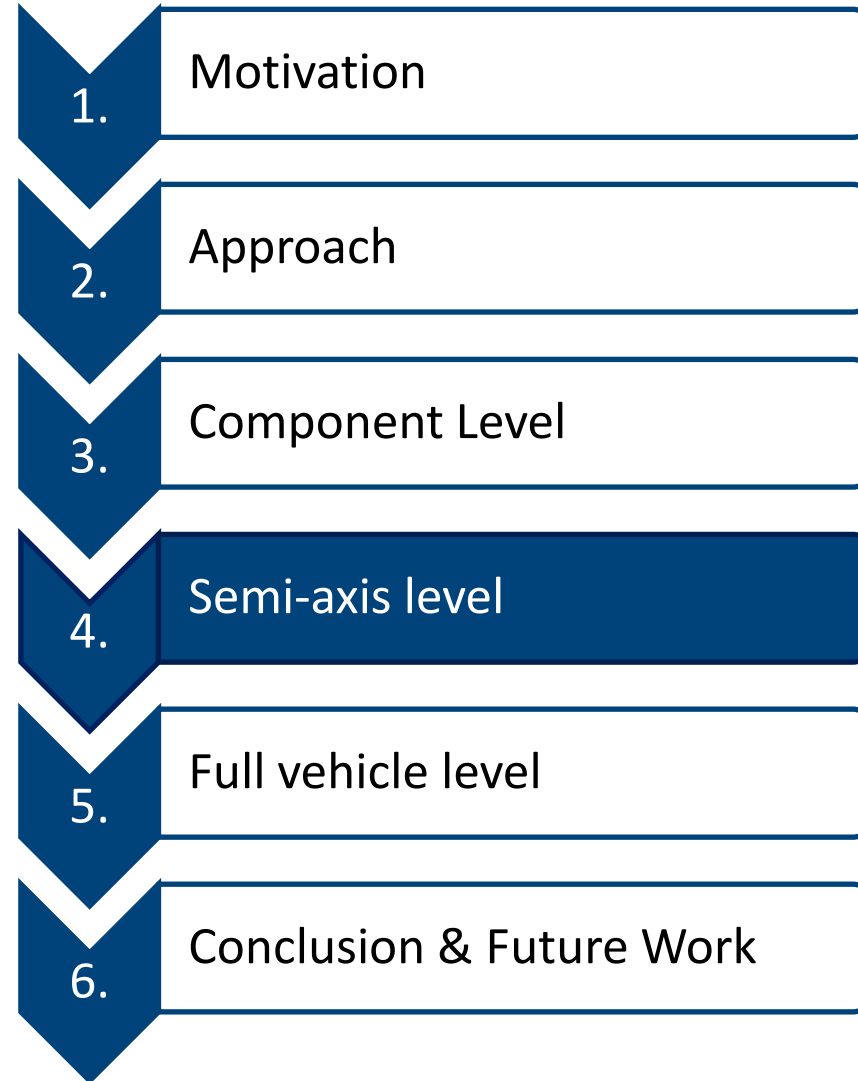
Compression Test



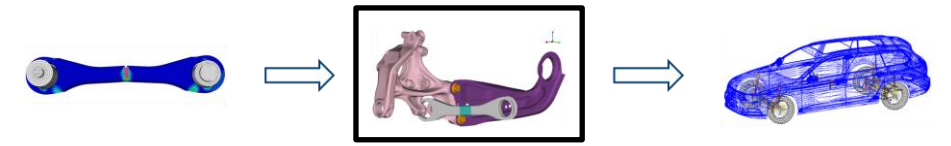
- FEA and experiment deliver similar results for the tie rod without a crack and the component with a long crack

→ Component stiffness is not reduced by the cracks

Agenda

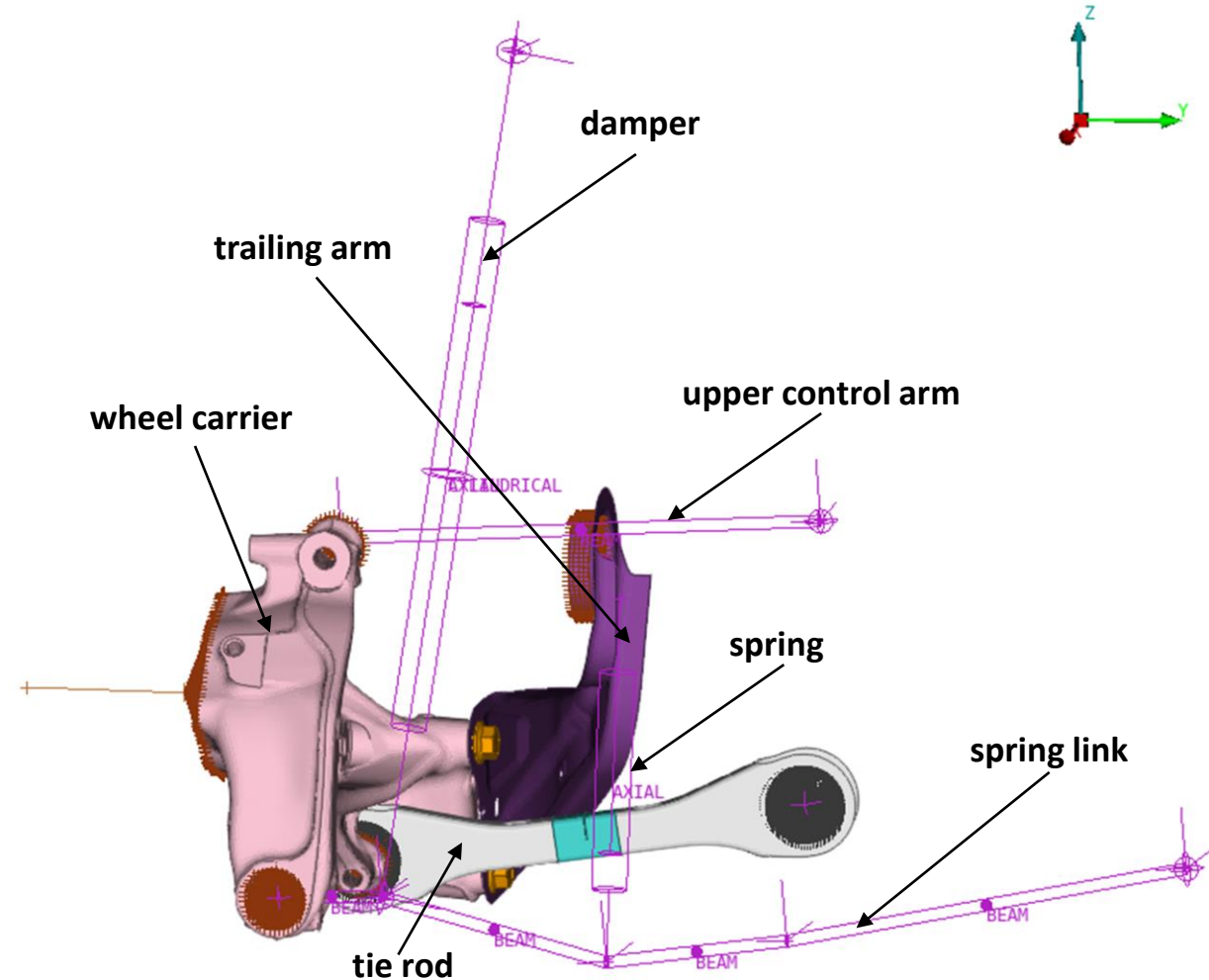


Semi-axis level

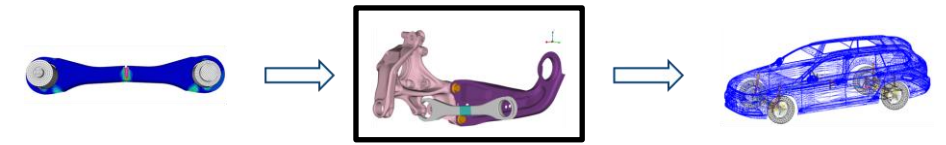


Model = semi four-link rear axle

- **Elastokinematics** (kinematic hardpoints & bearing characteristics) is **adopted** from the full vehicle model
- **Component modelling:**
 - Wheel carrier = rigid body
 - Trailing Arm = FE part (screw preload)
 - Spring link, upper control arm = beams
- **Computation:**
 - Nonlinear FEM
 - 3 analysis steps: bolt pretension, axle load, load case
 - Load case = left turn (0,75 g)

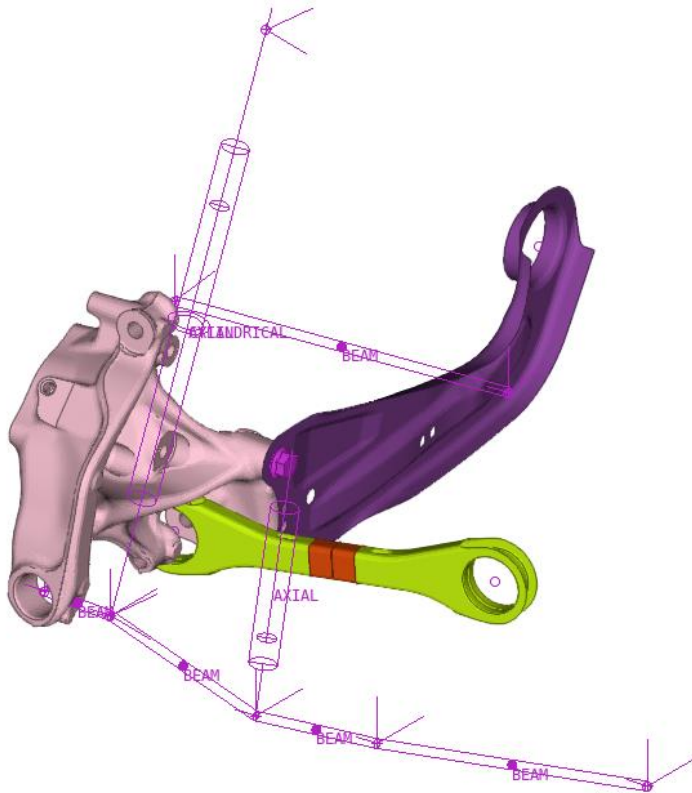


Semi-axis level

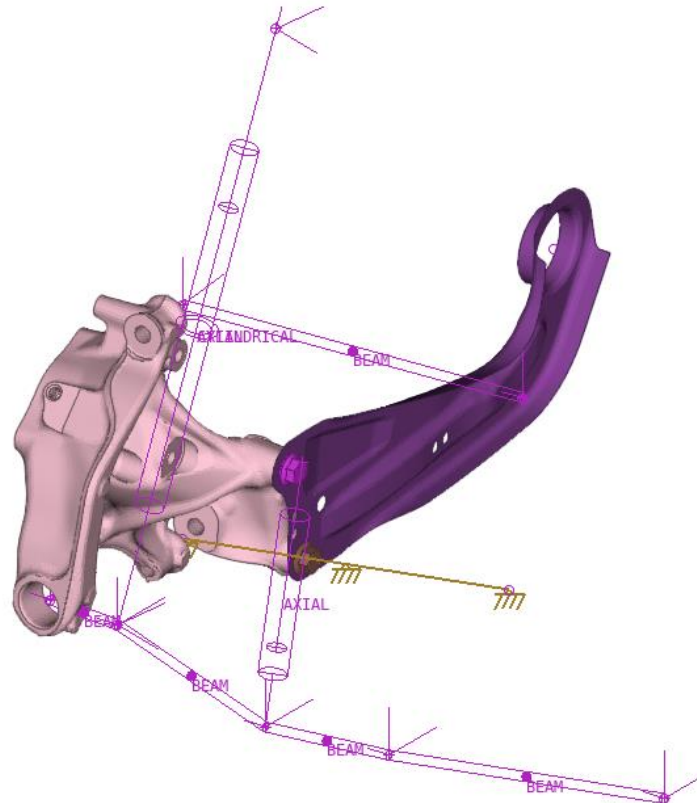


Tie rod modelling approaches

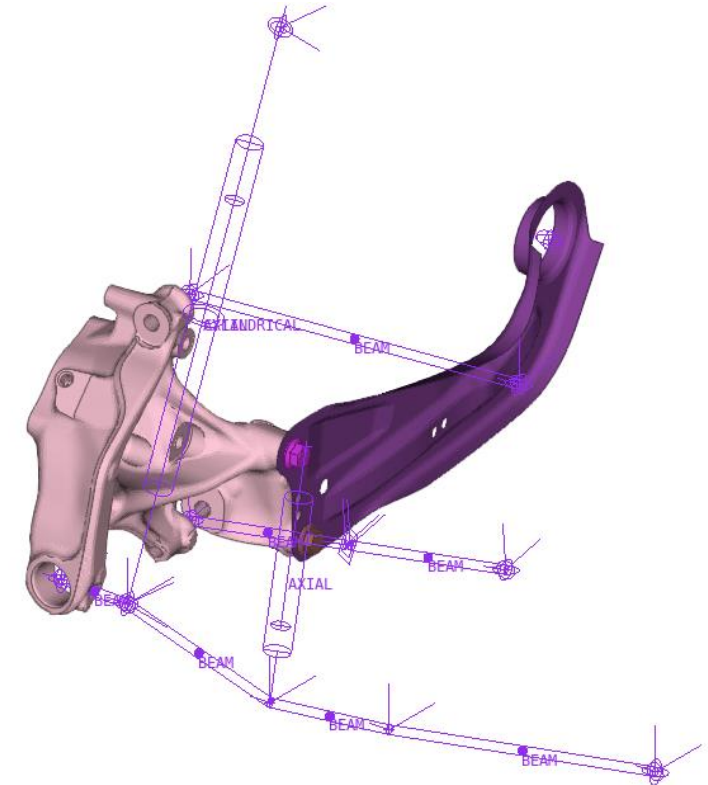
Nonlinear FEA



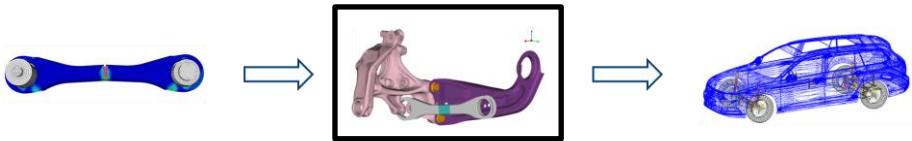
Model Neutral File (MNF)



Substitute Model



Semi-axis level



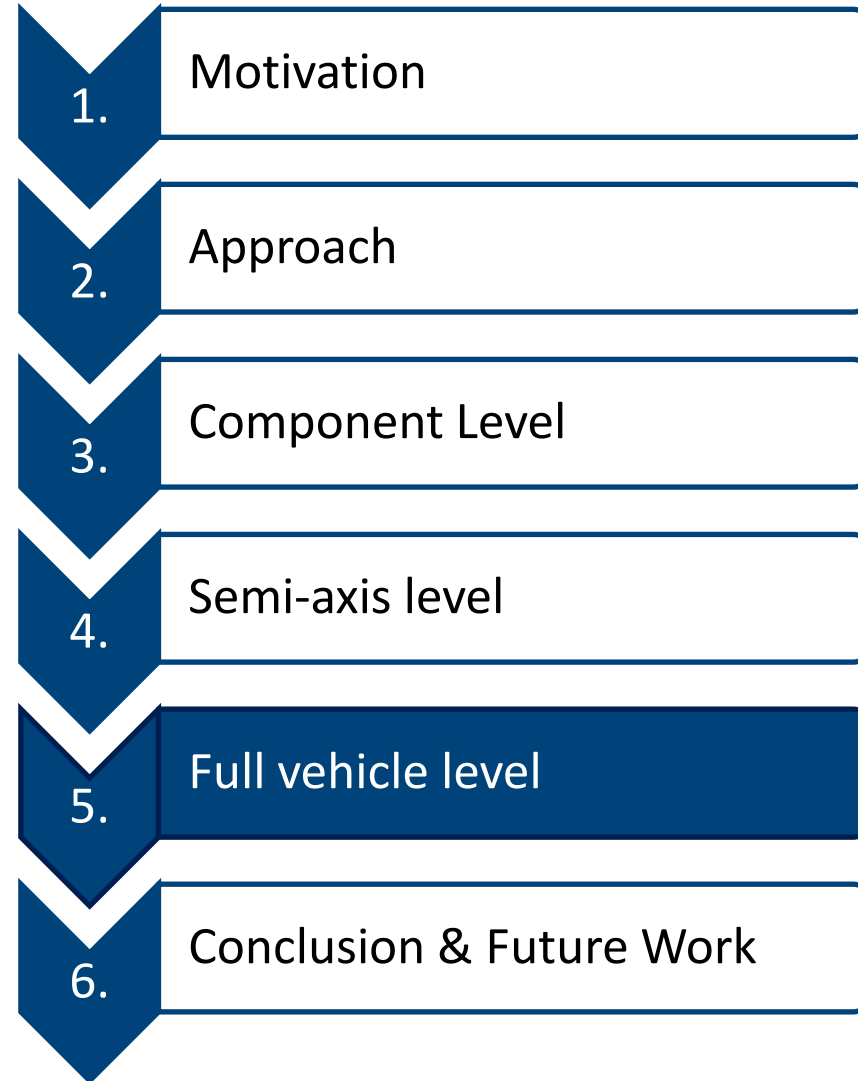
Camber angle difference in deg		Crack-free	Short Crack	Medium Crack	Long Crack
	Nonlinear FEA	-0.1257	-0.1264	-0.1323	-0.4736
	MNF	-0.1257	-0.1266	-0.1338	-0.2970
	Substitute Model	-0.1349	-0.1402	-0.1490	-0.48717

Toe angle difference in deg		Crack-free	Short Crack	Medium Crack	Long Crack
	Nonlinear FEA	-0.2259	-0.2267	-0.2337	-0.6289
	MNF	-0.2259	-0.2267	-0.2337	-0.3994
	Substitute Model	-0.24126	-0.24224	-0.25273	-0.65392

The non-linear effects of the long crack are not captured by the MNF, while the substitute model delivers good results.



Agenda

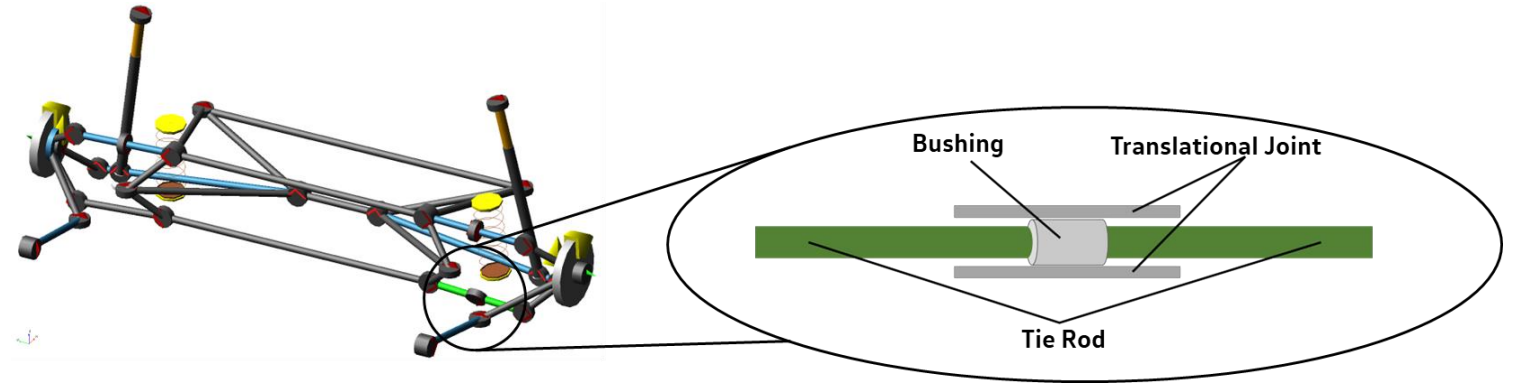


Full vehicle level



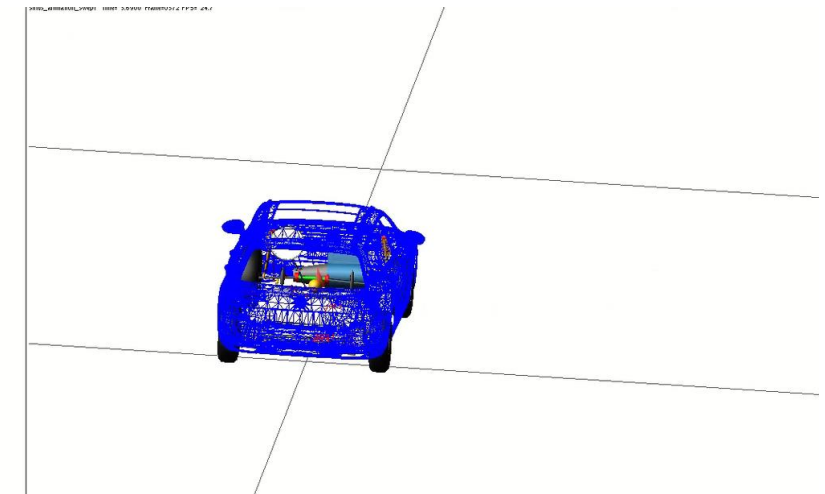
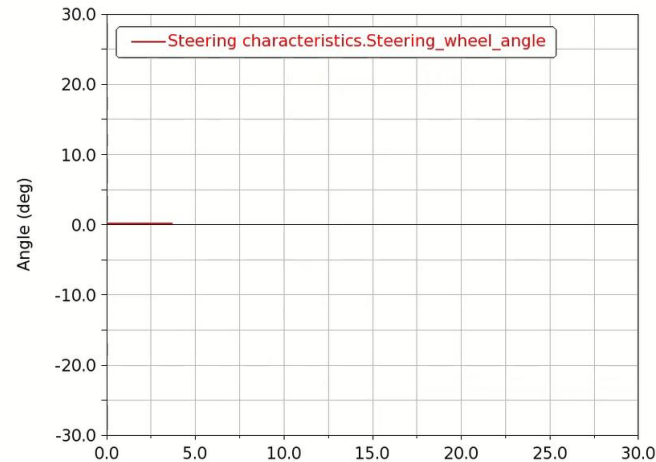
Tie rod modelling:

- Rigid body is replaced by substitute model
- Different crack lengths are realized by different stiffness characteristics



Sinus Sweep:

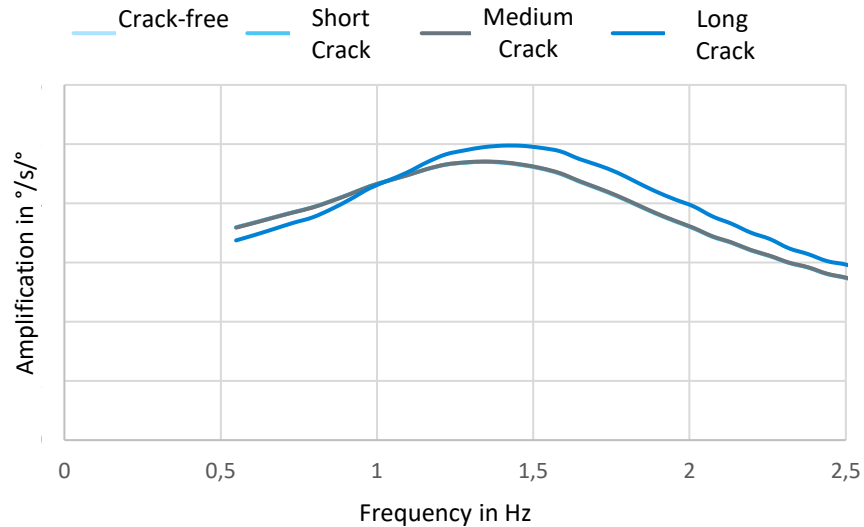
- 100 km/h
- SWA amplitude = 25 deg (0,4g)
- SWA frequency increases linear from 0,3 Hz up to 2,5 Hz



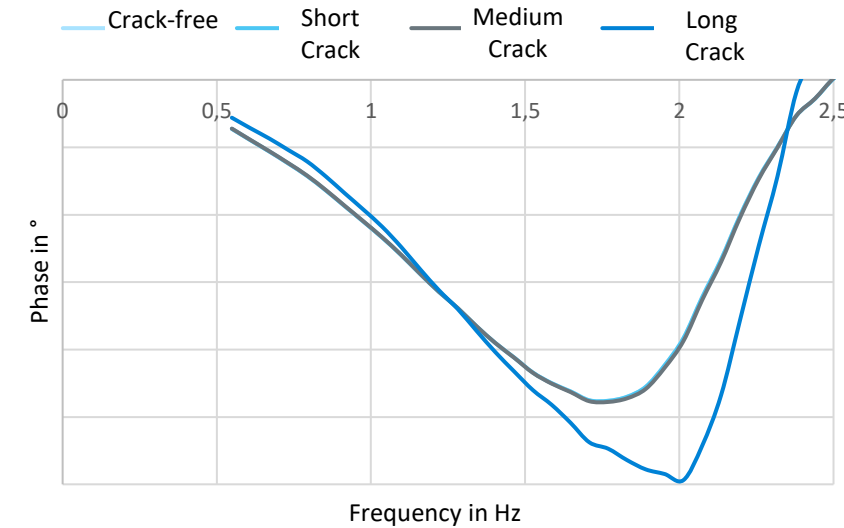
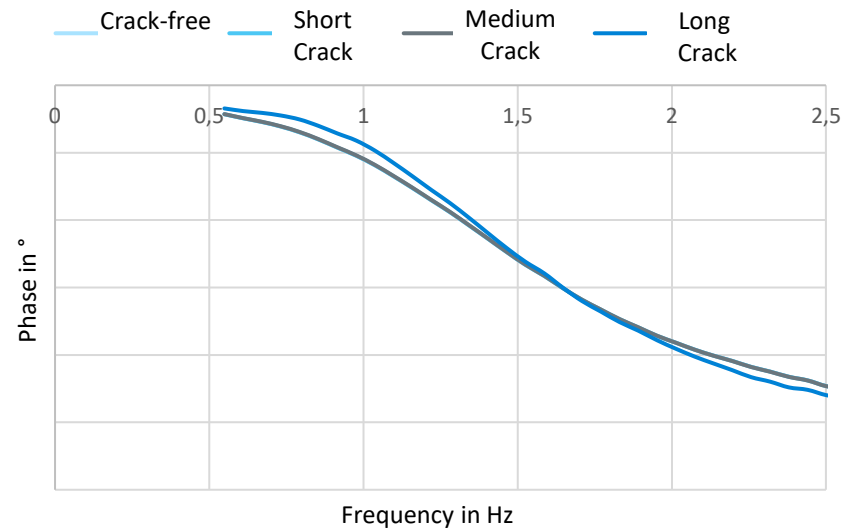
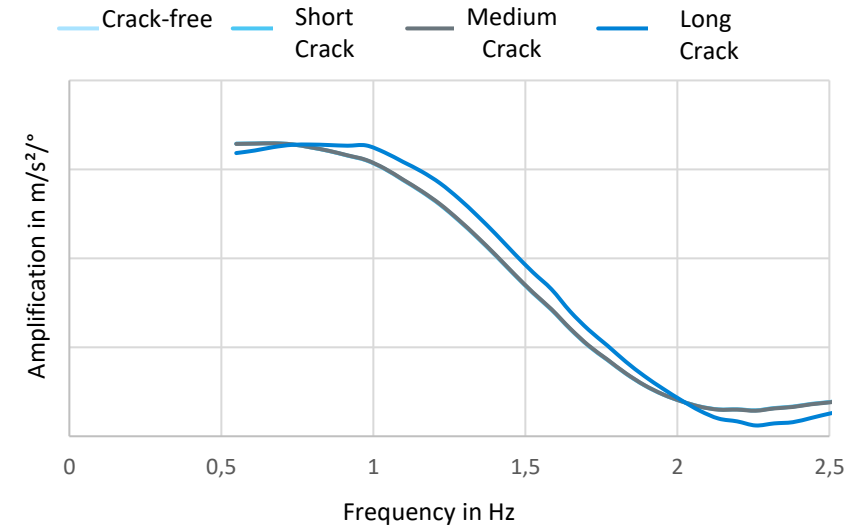
Full vehicle level



Yaw Rate/Steering Wheel Angle



Lateral Acceleration/Steering Wheel Angle

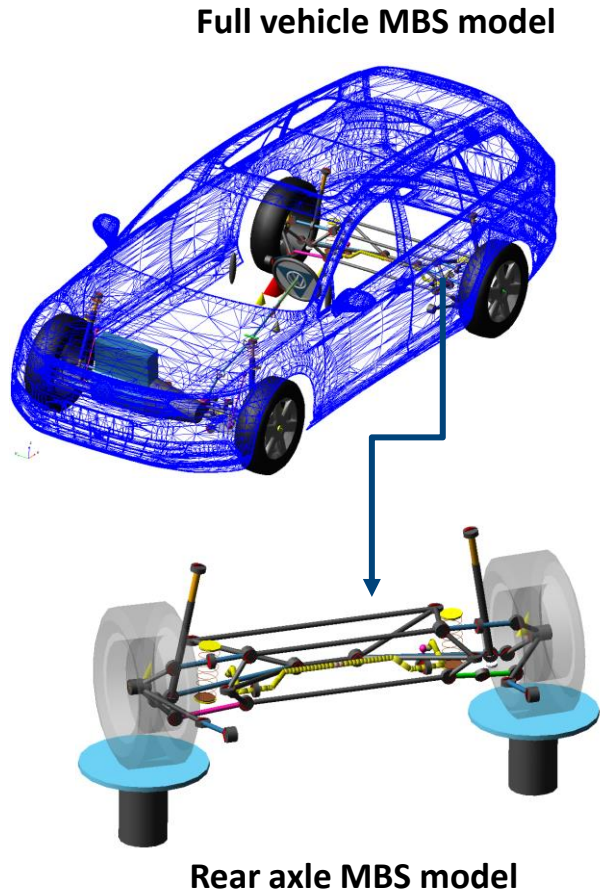


- Effects on driving dynamics only visible with the long crack
- Yaw gain and yaw natural frequency increase slightly
- Between 1.5 Hz and 2.5 Hz the delay time of the lateral acceleration increases slightly
- Amplification function hardly changes even with the long crack

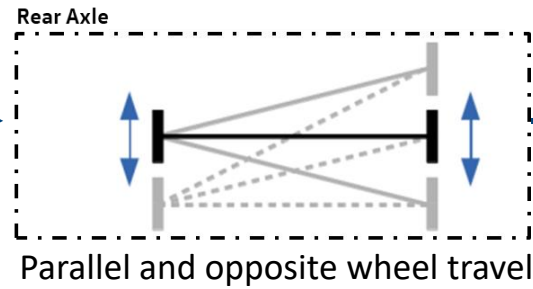
Full vehicle level



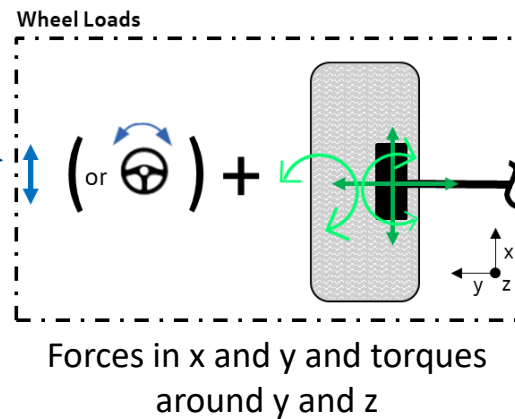
Process chain for generating a realtime-capable axle model:



2D Kinematic Characteristics



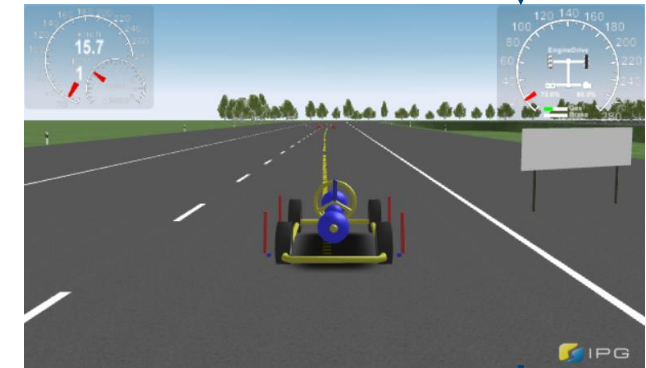
Elastokinematic Characteristics



Suspension Kinematics Compliance File (.skc)

- 6 DOF wheel carrier
- Length of spring, damper, antirollbar, buffer

Full vehicle CarMaker model



Dynamic driving simulator

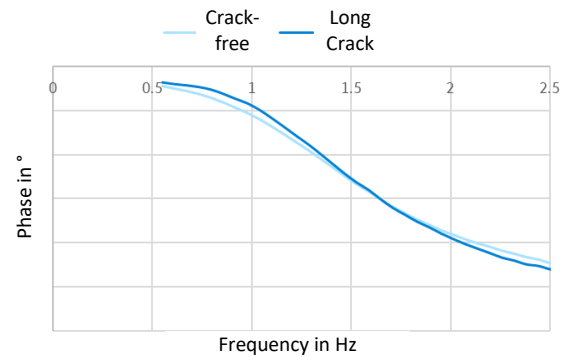
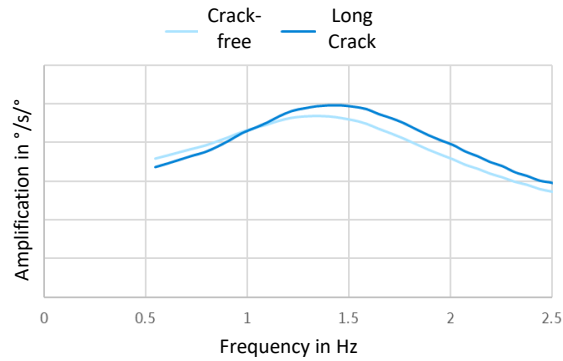


Full vehicle level

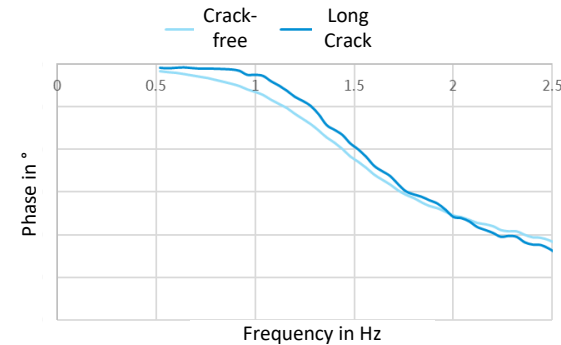
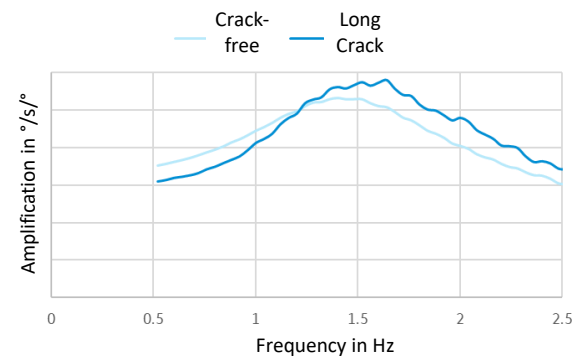


Yaw Rate/Steering Wheel Angle

ADAMS/Car

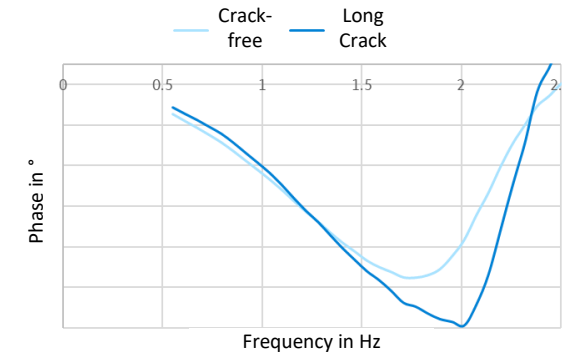
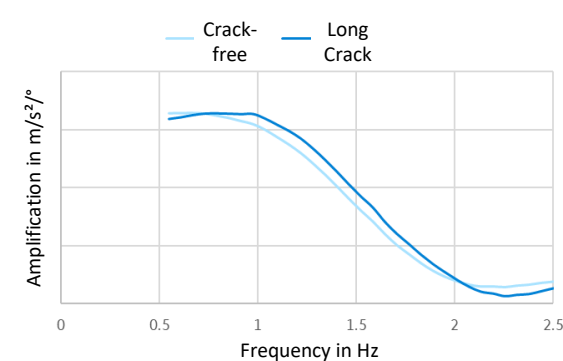


CarMaker

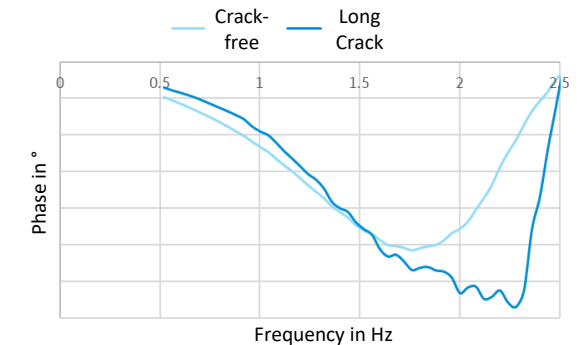
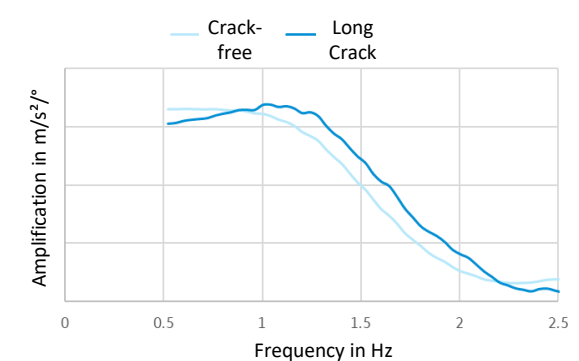


Lateral Acceleration/Steering Wheel Angle

ADAMS/Car

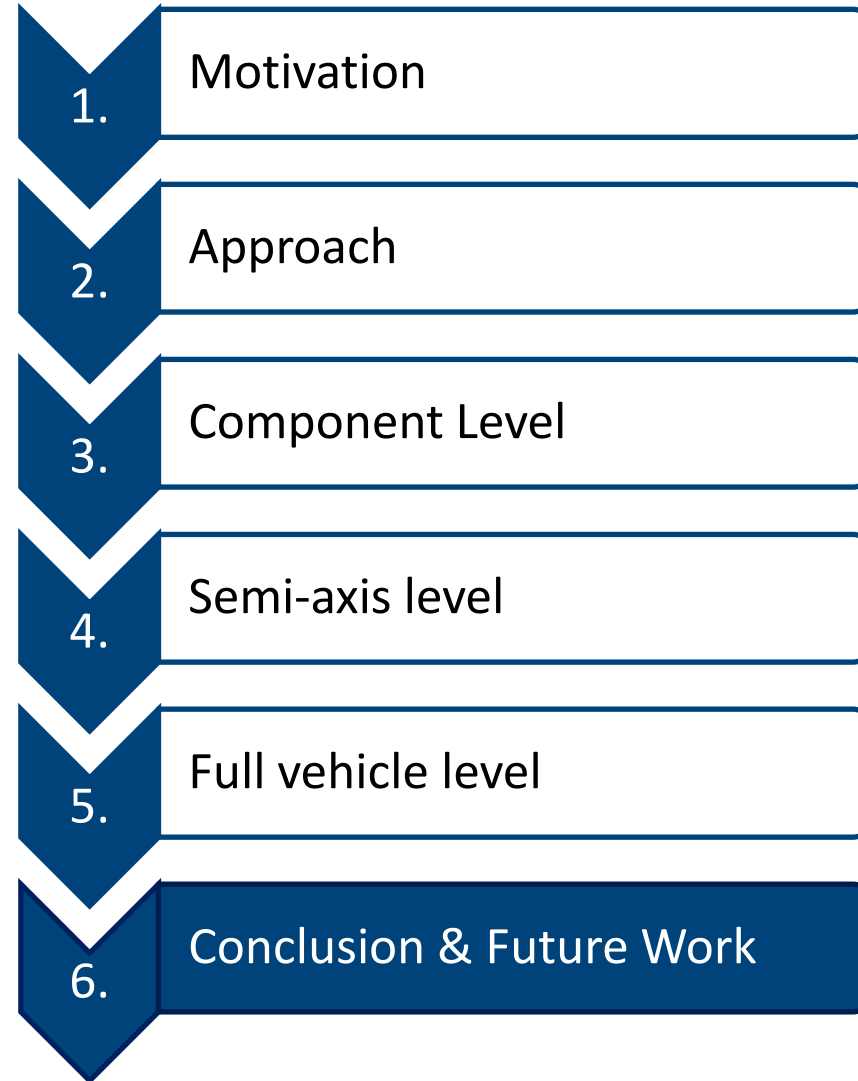


CarMaker



High agreement between the results of the MBS model and the real-time capable CarMaker model enables the application in the driving simulator.

Agenda



Conclusions



Conclusion: Cracks without component deformation in the tie rod should be avoided!

The **tie rod** has therefore been **designed** in such a way **that the probability of cracking and the crack propagation is very low:**

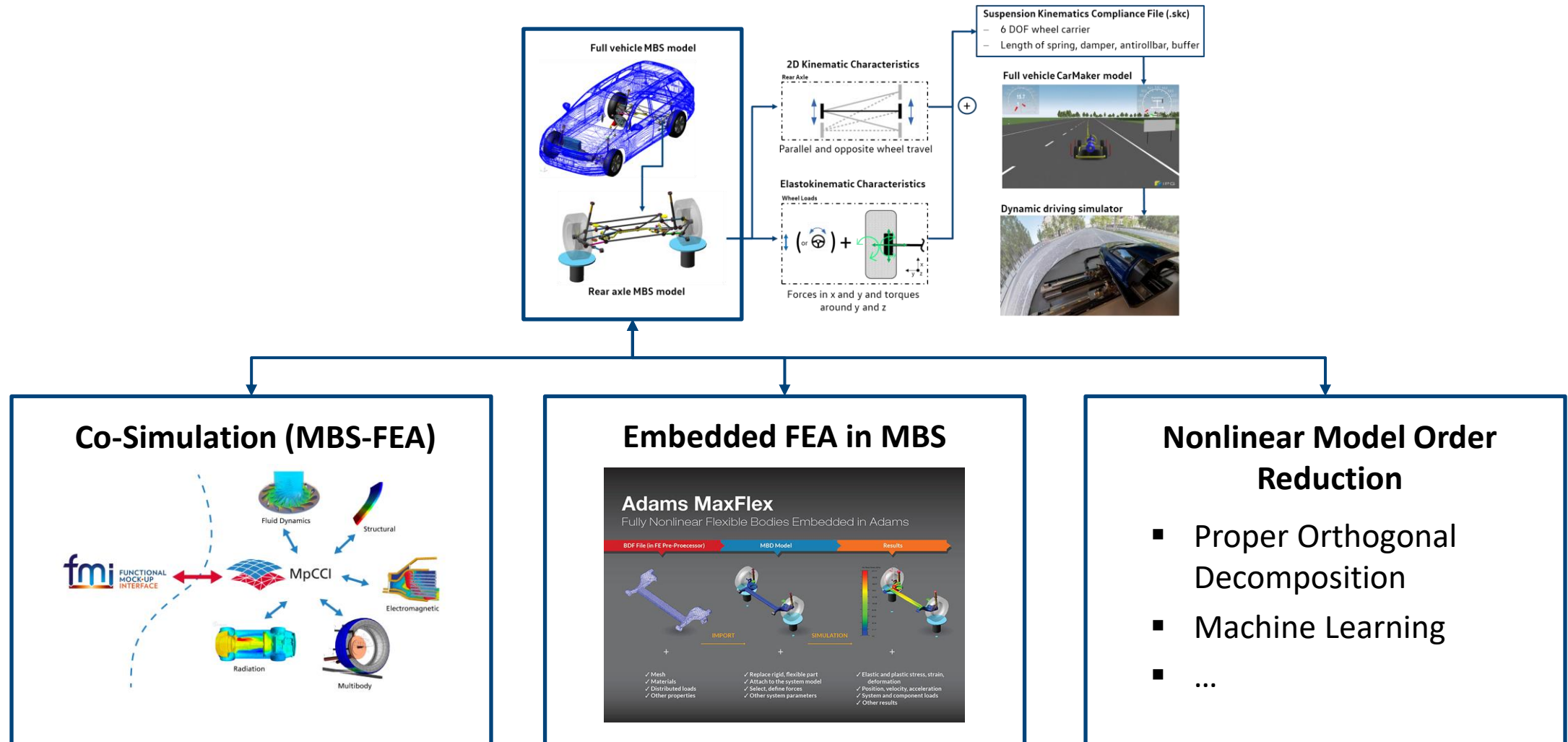
- Use of ductile steel with high strength
- Large sheet thickness
- Manufacturing by rolling for reinforcement
- Avoiding constructive notches (e.g. avoiding punching numbers)
- Half-sided opening of the component for the water drainage
- Good corrosion protection of the component

& Stresses on the tie rod far below the component strength and mainly tensile and compressive loads (no bending loads)



Future work

Generalization of the process chain for more complex components:



Thank you.

Robert Schurmann

PhD Student

Numerical Simulation Wheel Guidance System

Volkswagen Aktiengesellschaft

38436 Wolfsburg, Germany

