



Antriebs- und Fahrwerktechnik

Chassis Design using Composite Materials – MBS-Modeling and Experiences

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Calculations and Simulations
System Functions
ZF Friedrichshafen AG





Chassis Design using Composite Materials – MBS-Modeling and Experiences

Task

- Creating axle models for the design of lightweight axles with fiber reinforced plastic components
- Elastic struts define kinematics & compliance of axle
- Exact kinematics of elastic bodies is important
- Fast models for advanced engineering projects

Contents

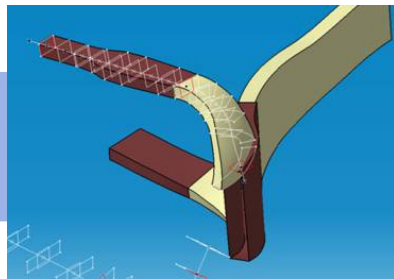
- Modeling of Elastic Components
 - ◆ Experiences, Improvements, Correlation
- Automated Postprocessing





Modeling of Elastic Components

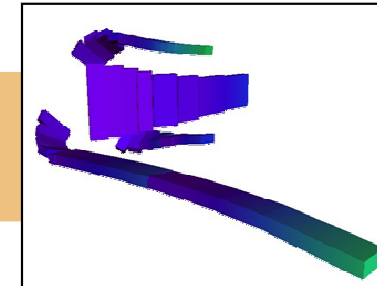
- Elastic bodies are discretised using beam elements
 - ◆ Geometric stiffening terms yield non-linear kinematics
 - ◆ MBS: isotropic material



CAD Modell
with geometric data
Export geometry

```
refsys ( 1, $B_Isys ) = 1
*** Inertial/Kinematic Reference Frame ***
marker ( 1, $M_Isys ) = $B_Isys
marker ( [-] Assignment: Marker -> Body ) = $B_Isys
marker ( 1, $M_Isys_DmyStr1 ) = $B_Isys
marker.pos ( 1, $M_Isys_DmyStr1 ) =
$Vit_RAC_Sus_HLX_Chs_TLS' ! [m] Built-in Position
marker ( 2, $M_Isys_DmyStr2 ) =
$Vit_RAC_Sus_HLY_Chs_TLS' ! [m] Built-in Position
marker.pos ( 2, $M_Isys_DmyStr2 ) =
$Vit_RAC_Sus_HLZ_Chs_TLS' ! [m] Built-in Position
marker ( 1, $M_Isys_DmyStr3 ) = $B_Isys
marker ( [-] Assignment: Marker -> Body ) =
marker.pos ( 1, $M_Isys_DmyStr3 ) =
$Vit_RAC_Sus_HRX_Chs_TLS' ! [m] Built-in Position
marker ( 2, $M_Isys_DmyStr4 ) =
marker.pos ( 2, $M_Isys_DmyStr4 ) =
$Vit_RAC_Sus_HRY_Chs_TLS' ! [m] Built-in Position
marker ( 3, $M_Isys_DmyStr5 ) =
marker.pos ( 3, $M_Isys_DmyStr5 ) =
$Vit_RAC_Sus_HRZ_Chs_TLS' ! [m] Built-in Position
```

Scripts to generate
SIMPACK source code



SIMPACK
Simbeam Modell



- automated generation of Simbeam definitions
 - ◆ manual generation of FBI and SID-Files (FEMBS)
 - ◆ manual assembly and calculation of preload

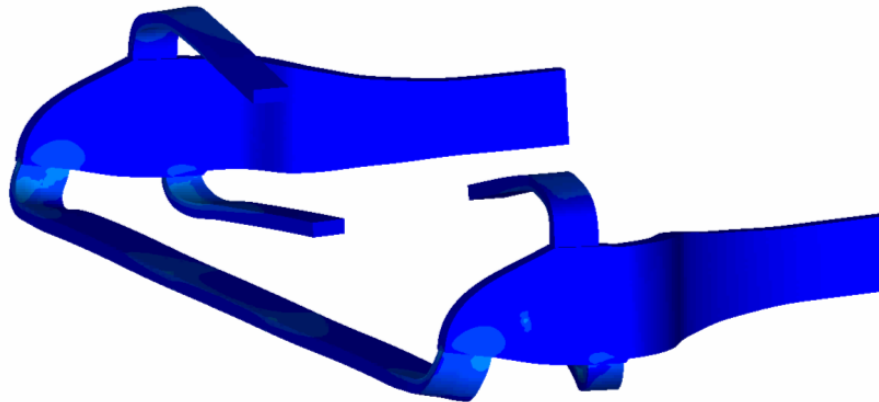


Modeling of Elastic Components

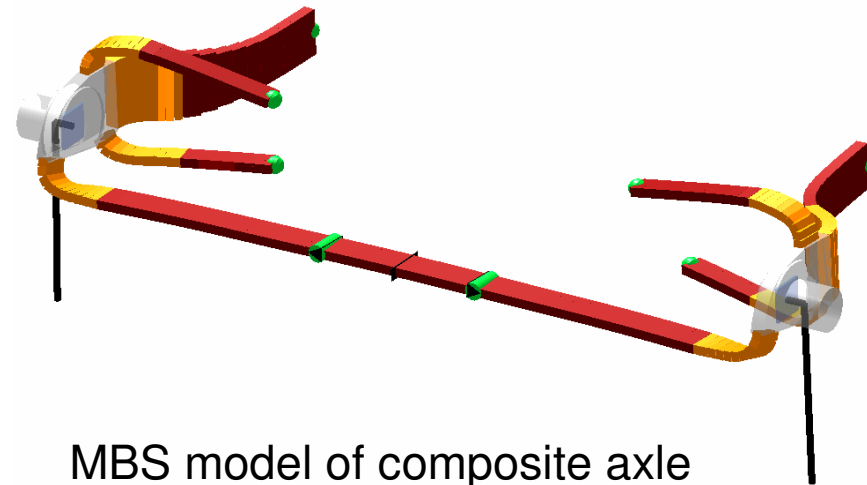
First comparison MBS – FEM

→ Specification of axle

- ◆ Design concept: one body with integrated flexible components
- ◆ FEM: Orthotropic material – MBS: Isotropic material
- ◆ Comparison of deformations and rotations at wheel centre
- ◆ Good correlation of results



FE model of composite axle



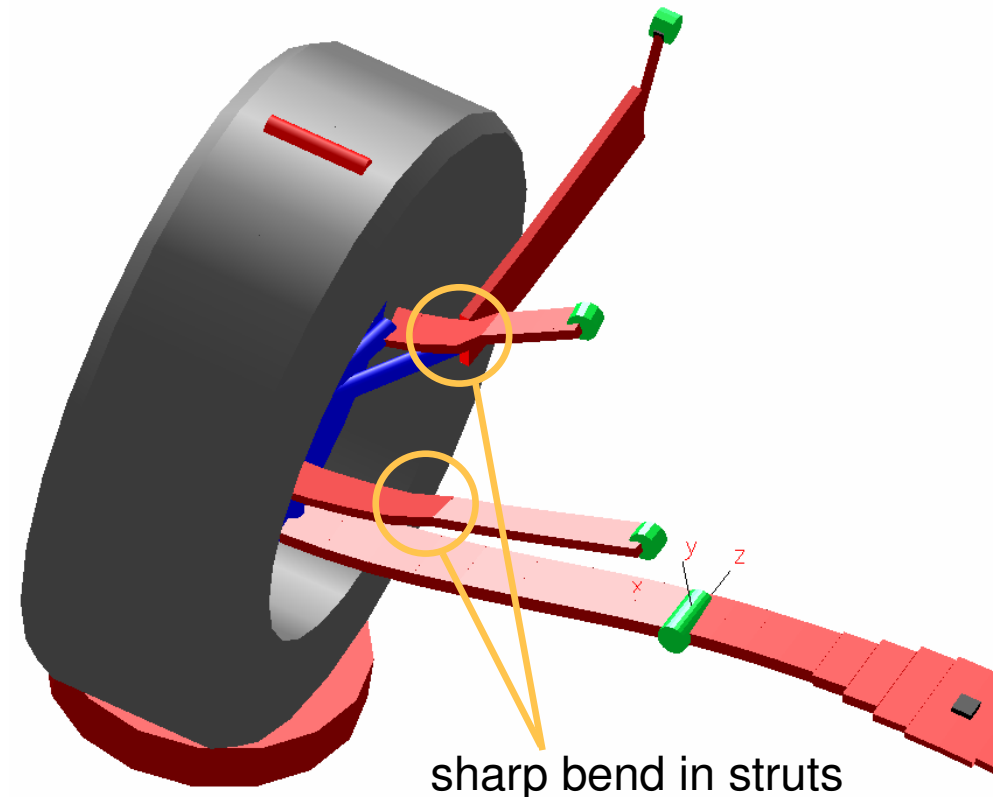
MBS model of composite axle



Modeling of Elastic Components

Experiences

- Use of modeling approach for investigation of several axle concepts
- Intermediate version of axle design:
Non plausible sharp bend in struts under wheel load
- Reasons:
 - ◆ no physical buckling
 - ◆ elastic struts are composed of two segments
 - ◆ due to parameterised assembly definition:
poor numerical conditions





Modeling of Elastic Components Improvements

- Problem solving: SIMPACK AG and ZF Friedrichshafen AG
- Improvements in SIMPACK
 - ◆ Orientation of markers is defined by quaternions (starting SIMPACK 8903beta)
- Changed approach to couple segments of elastic bodies
 - ◆ 6 dof joints for reference system
 - ◆ additional 6 dof constraint to couple the segments
- Approach has been verified in several following models
 - ◆ comparison with nonlinear FE results
- Stable Simulation results for several variations of axle
 - ◆ even with extreme deformations



Modeling of Elastic Components

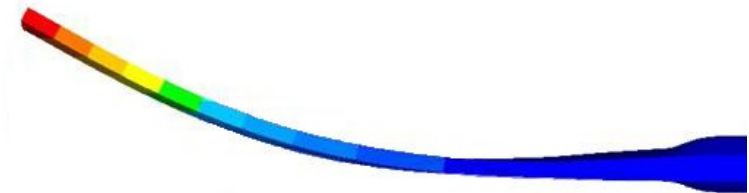
Correlation of SIMPACK with nonlinear FEM

→ Deformation of a single elastic strut at maximum deflection and different load cases

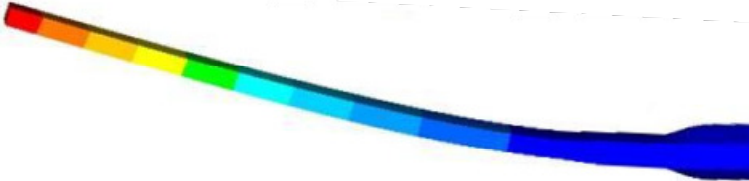
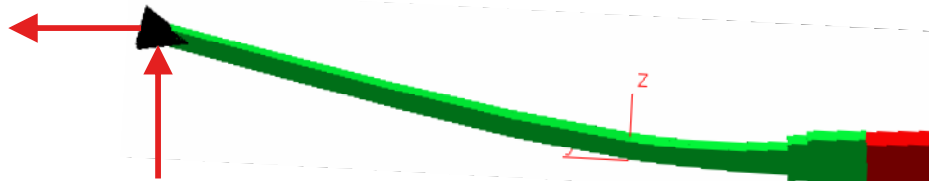
1. additional bending due to compression force

SIMPACK
isotropic material

FEM
orthotropic material



2. straightening due to tension force

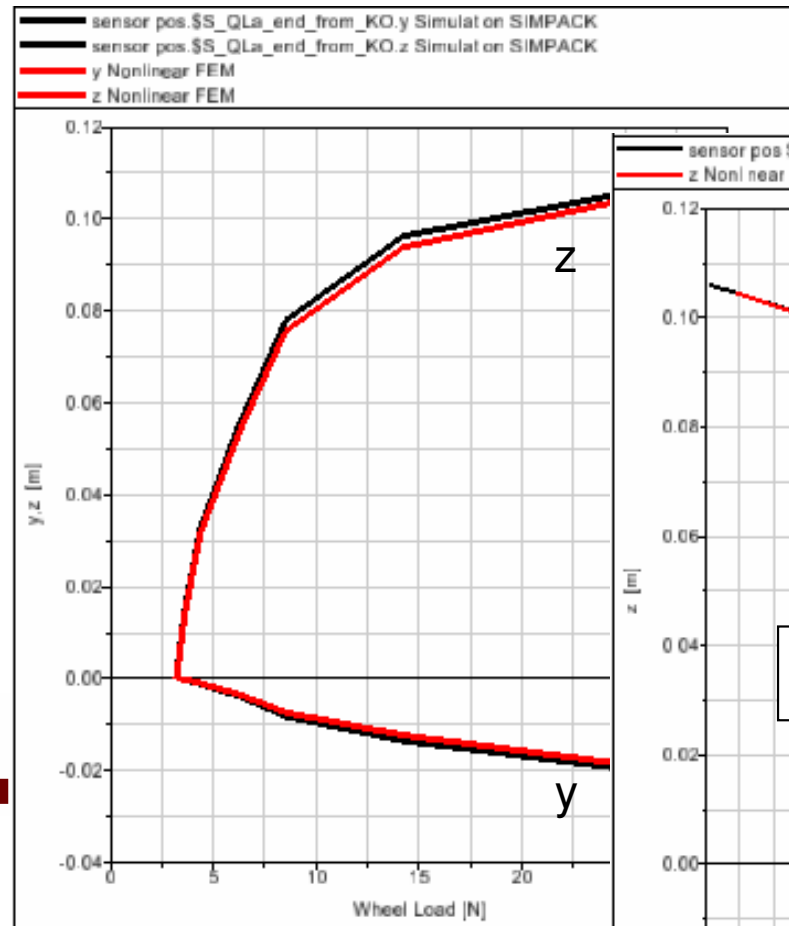




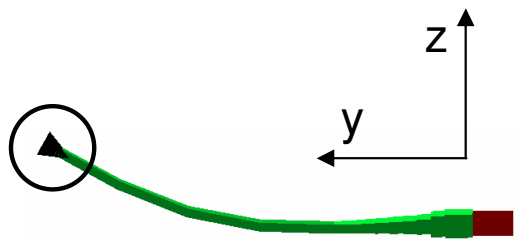
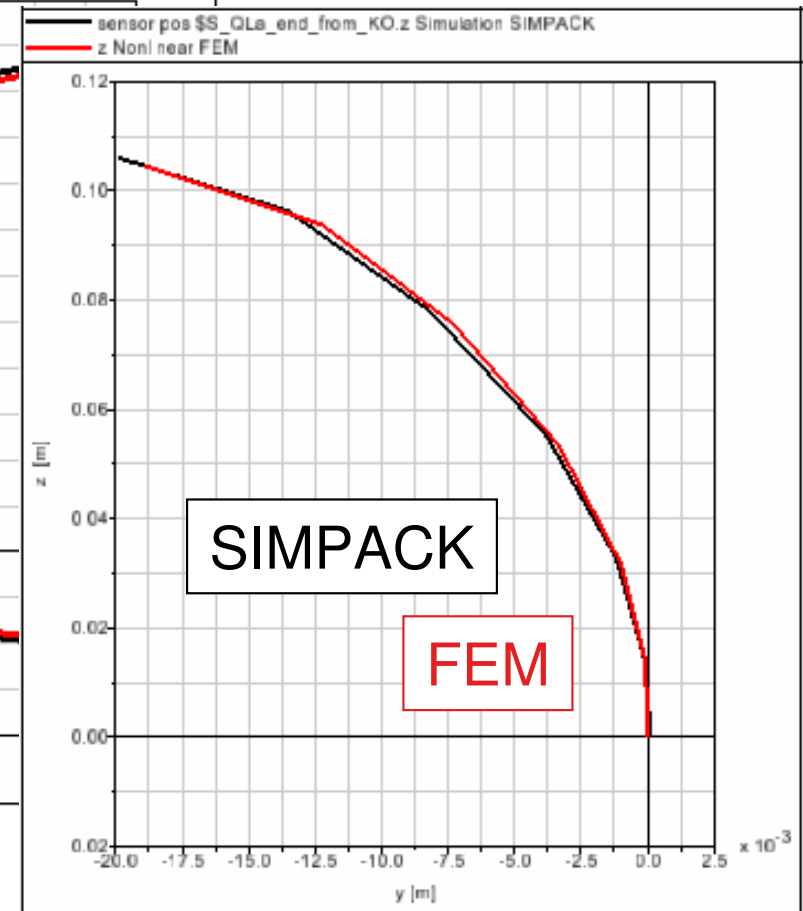
Modeling of Elastic Components

Correlation of MBS with FEM

Deformation over Wheel Load



Path of End Point



→ Good correlation of nonlinear kinematics

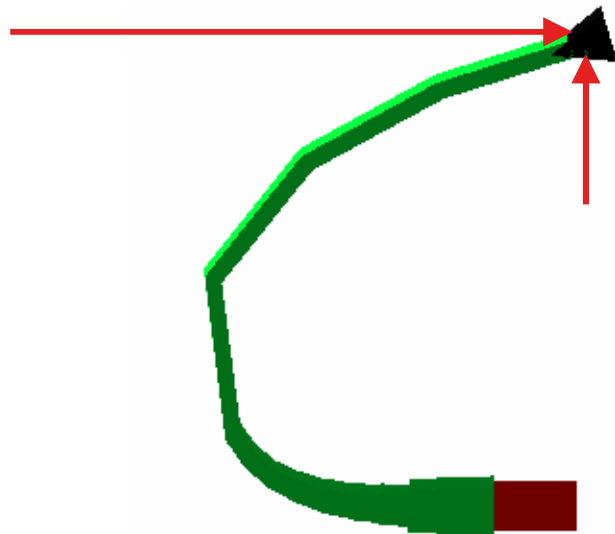


Modeling of Elastic Components

Robustness of the approach

- calculation of single strut without axle assembly
- unrealistic high compression load on struts
- second stable static equilibrium is found by SIMPACK and FEM
- robust simulation even beyond field of application

SIMPACK



FEM

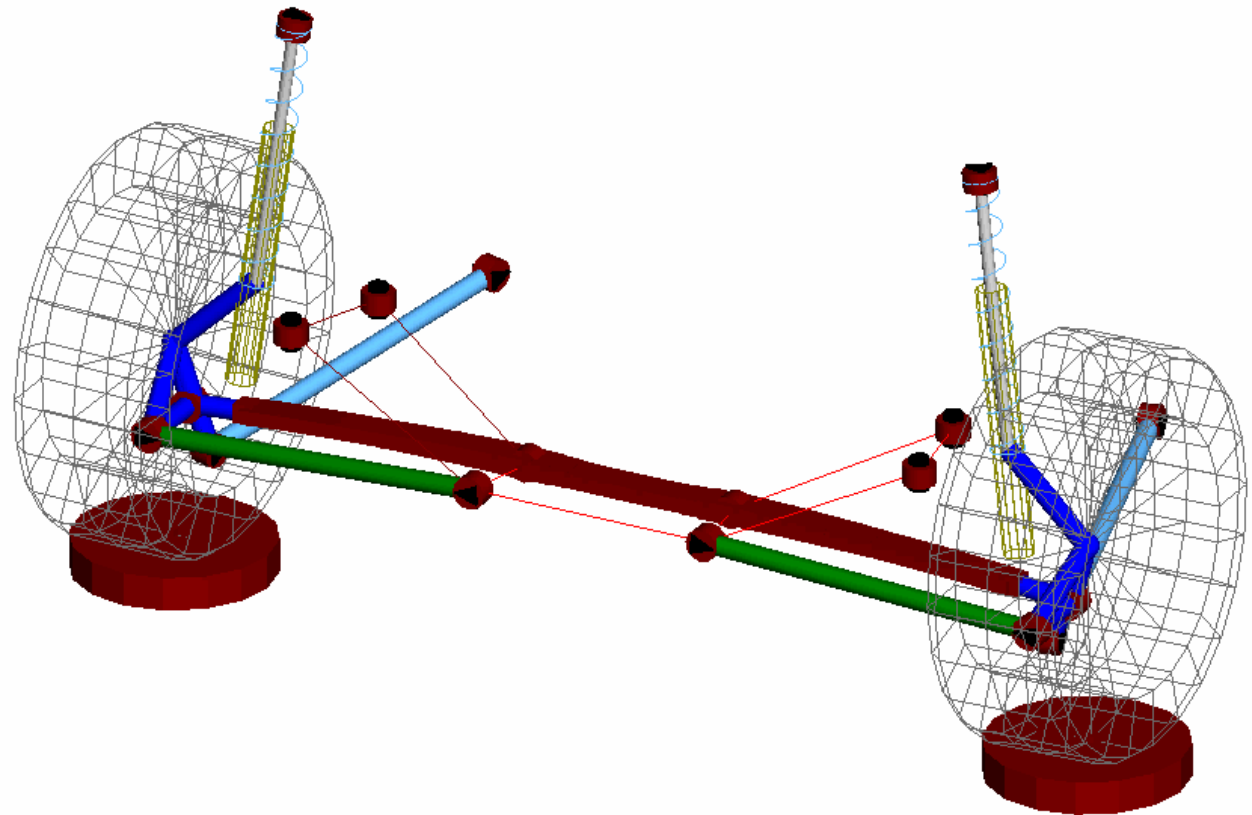




Automated Postprocessing

Virtual K&C Test Rig

- parallel wheel travel
- opposite wheel travel
- brake / drive torques
- lateral forces at tire contact point





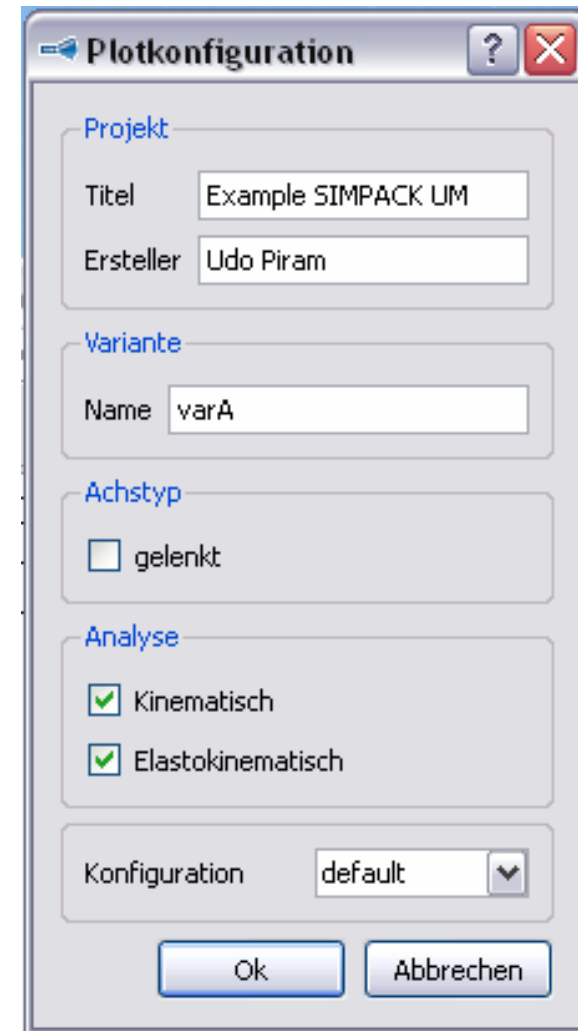
Automated Postprocessing



Main script

- Starting a new project
- Adding curves

- Calculation of typical axle parameters
- Generation of plots incl. scaling, windowing ...
- Up to 4 variants in one plot
- Language can be selected globally





Automated Postprocessing

Scalar Axle Parameters (Example Numbers)

Achskennwerte in Konstruktionslage (KL)

	A (Initial Design)	B (Changed Hardpoints)	
kinematisch:			
Vorspur in mm:	-2.835	-2.866	
Radsturz in Grad:	-1.061	-1.066	
Bremsabstützwinkel in Grad:	31.878	32.105	
Schrägfederung in Grad:	2.652	2.932	
Rollzentrumshöhe in mm:	89.042	88.968	
Rollzentrumänderung in mm/mm:	1.622	1.698	
Federübersetzung:	0.996	0.997	
Dämpferübersetzung:	1.008	1.009	
Nachlaufwinkel in Grad:	---	---	
Spreizung in Grad:	---	---	
Nachlaufstrecke in mm:	---	---	
Lenktradius in mm:	---	---	
Spreizungsversatz in mm:	---	---	
Nachlaufversatz in mm:	---	---	
Radlasthebelarm in mm:	---	---	
elastokinematisch:			
Vorspur in mm:	-2.835	-2.866	
Radsturz in Grad:	-1.061	-1.066	
Radlast in kN:	3.439	3.466	
Radfederrate gleichseitig in N/mm:	33.737	30.224	
Radfederrate wechselseitig in N/mm:			

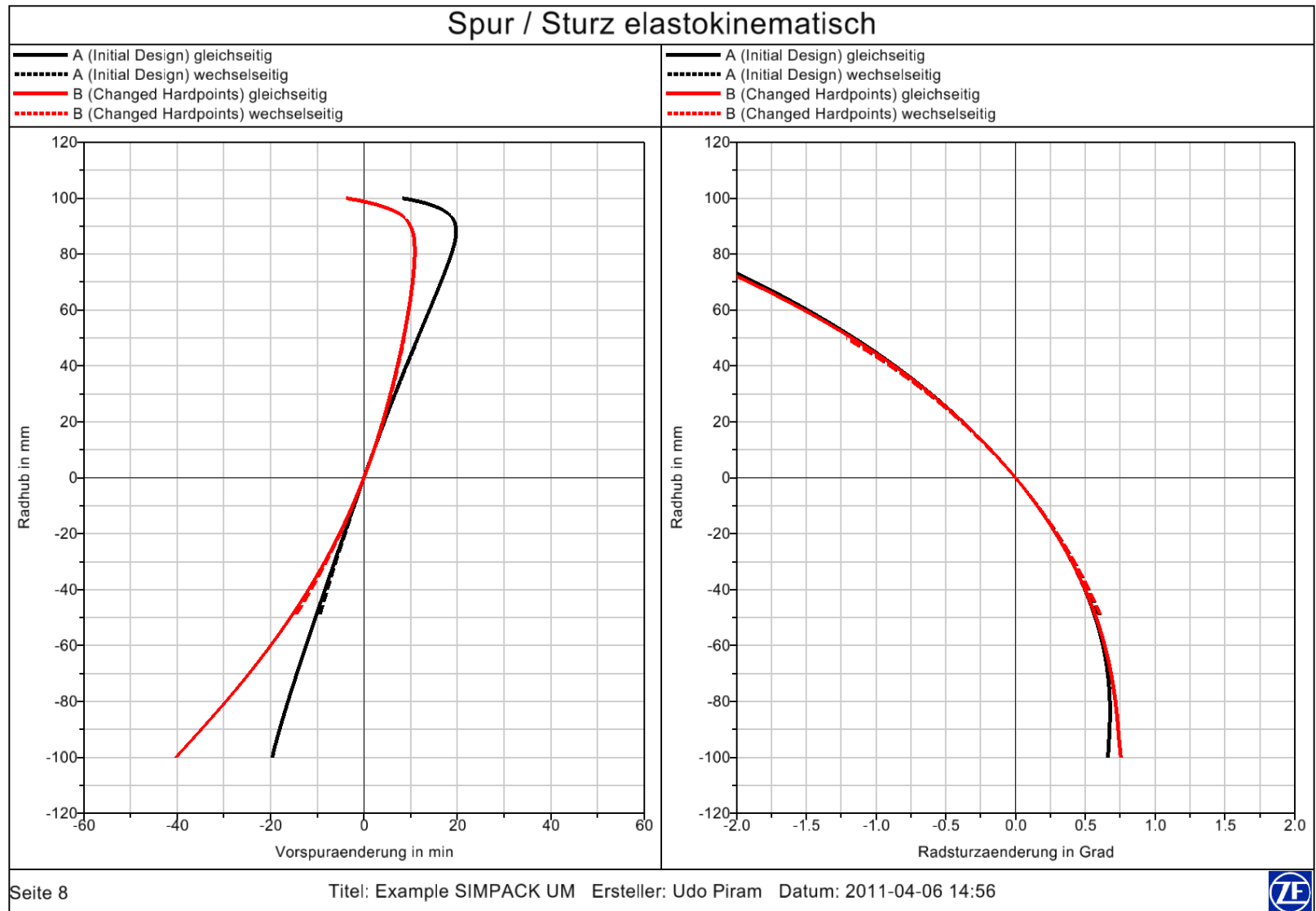
elastokinematisch:

Vorspur in mm:	-2.835	-2.866
Radsturz in Grad:	-1.061	-1.066
Radlast in kN:	3.439	3.466
Radfederrate gleichseitig in N/mm:	33.737	30.224
Radfederrate wechselseitig in N/mm:	49.122	45.624



Automated Postprocessing

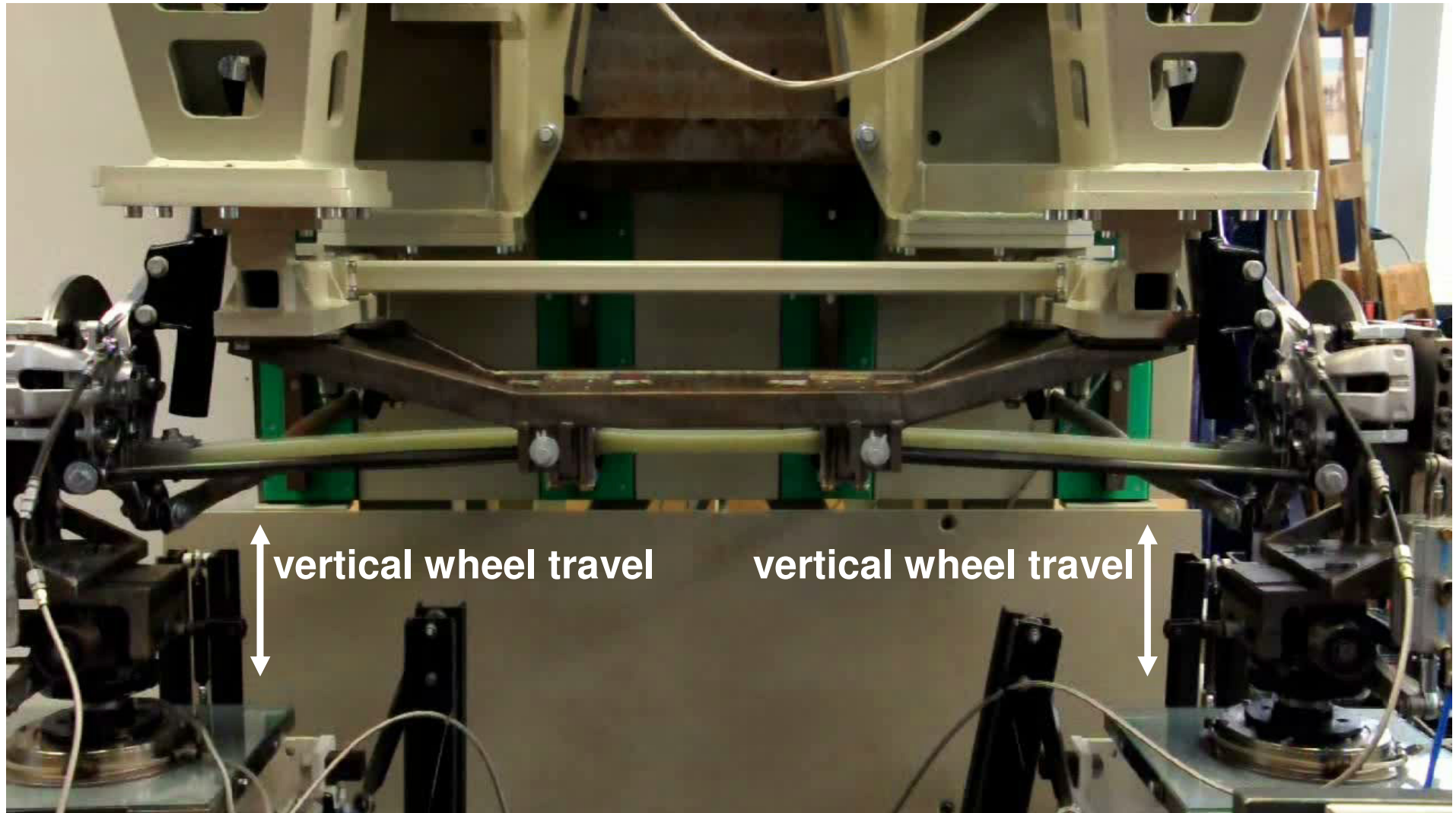
Example Plot





Automated Postprocessing

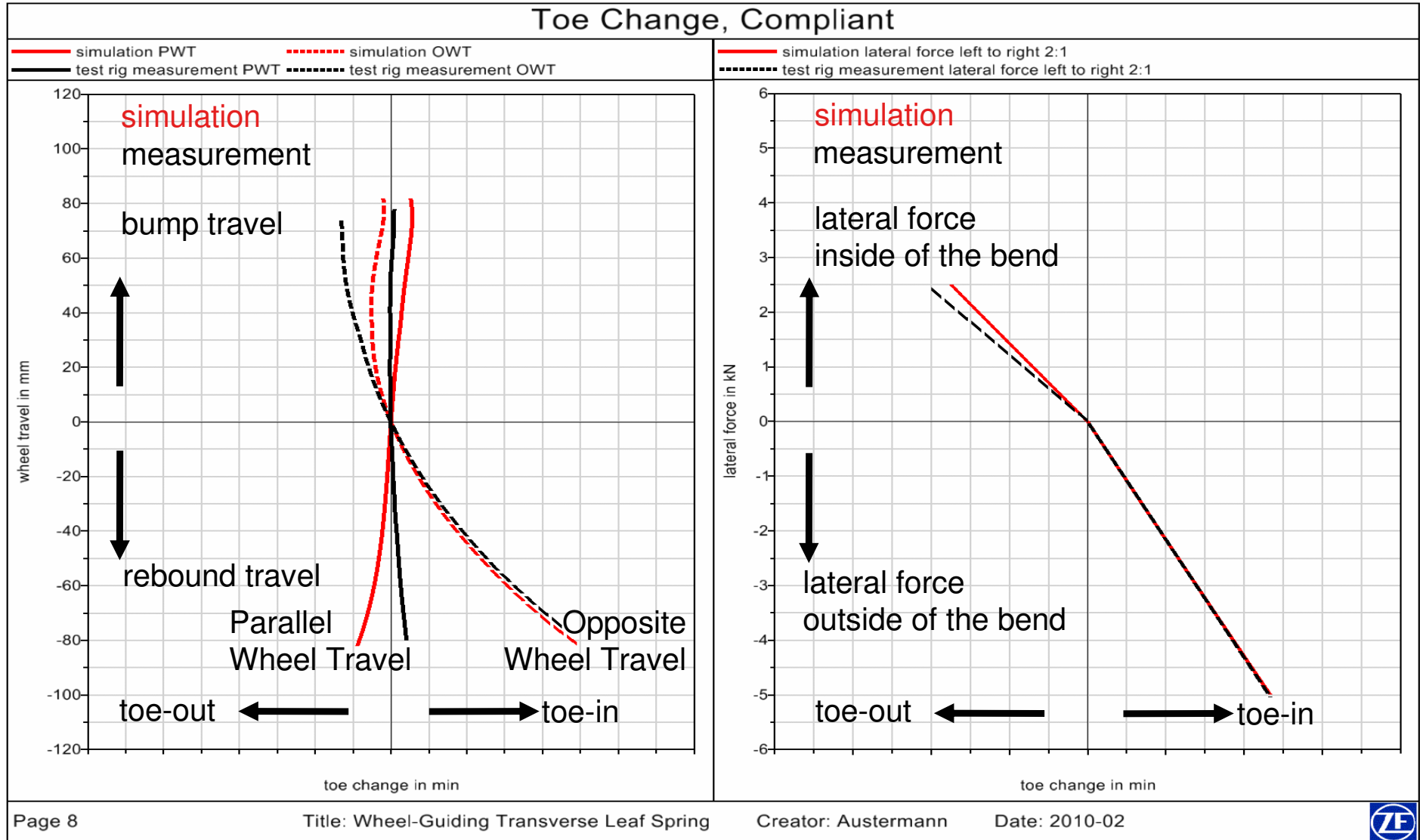
Wheel-Guiding Transverse Leaf Spring





Automated Postprocessing

Correlation with K&C test bench





Summary

- SIMPACK models of elastic axle components made of composite material using Simbeam elements
 - Automated creation of beam models using scripts
 - 😊 Approach was successfully used in several axle design projects
 - 😞 Manual generation of FBI and SID-Files (FEMBS)

- Automated Postprocessing of K&C-Simulation
 - Standard Simulation Maneuver
 - 😊 Scripting Language of SIMPACK to generate plots and key figures