Creep Forces in Simulations of Traction Vehicles Running on Adhesion Limit

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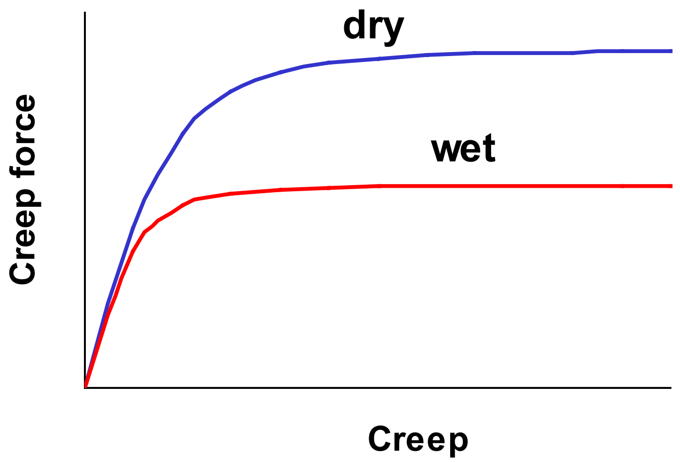
Contents

- Demand for model of creep forces for simulations of traction vehicles running on adhesion limit
- Calculation of creep forces in multi-body dynamics
  - A time-saving method
- Extension of creep force model by decreasing friction coefficient
  - Limitations of this method
- New model of creep forces for traction vehicles running on adhesion limit
- Parameter identification from measurements
- Model validation by comparison of simulations and measurements
- Conclusions

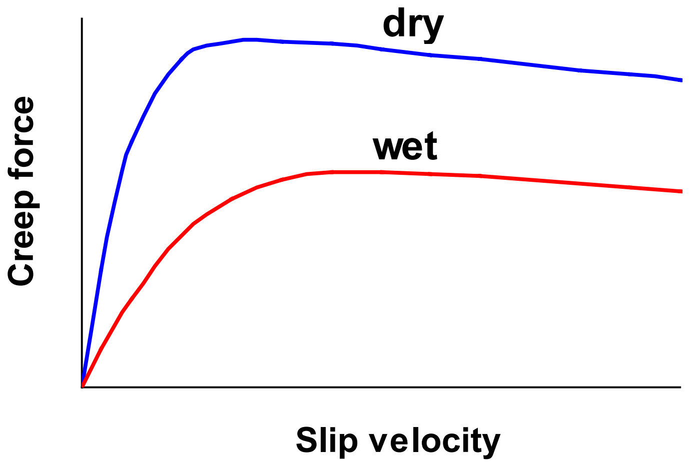
Creep Force Models in Vehicle Dynamics and Drive Dynamics => Demand of one Common Model

Vehicle Dynamics



- Possible for use in vehicle dynamics (small creep)
- Used for longitudinal and lateral directions
- Function of creep

Drive Dynamics



- Necessary for drive dynamics (large creep - slip)
- Usually used only for longitudinal direction
- Function of slip velocity

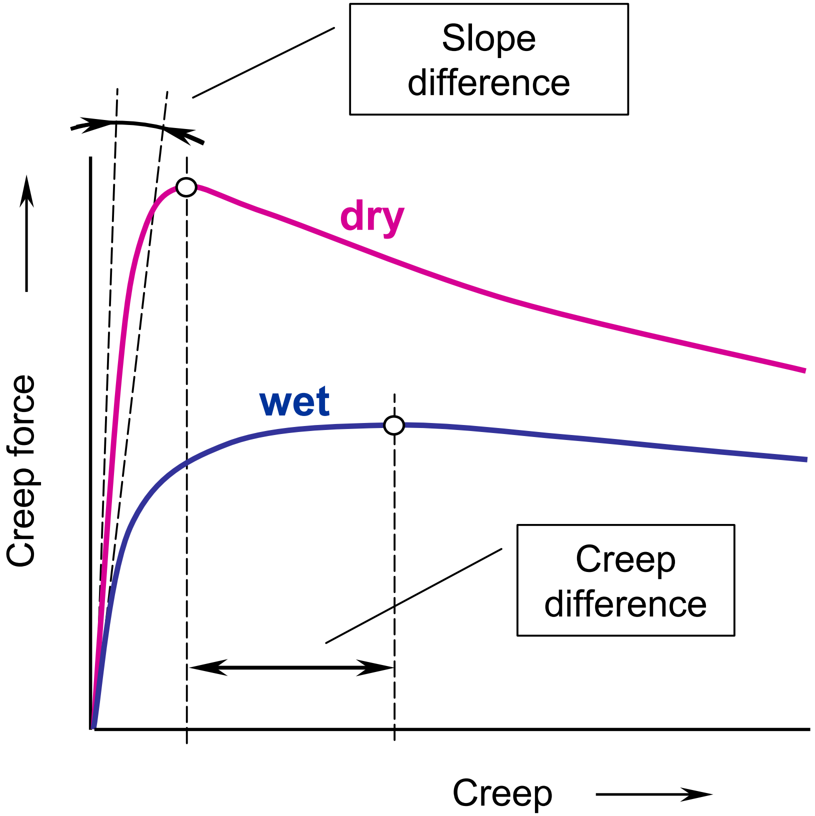
Demand for Creep Force Model Suitable for Simulations of Traction Vehicles Running on Adhesion Limit

Difference dry - wet rail:

- Reduced initial slope
- Adhesion optimum at large creep on wet or polluted rail

State-of-the-art:

- Modells with decreasing section published
- Agreement only for dry and clean contact conditions
- No simple model to simulate real wet and/or polluted conditions



Calculation of Creep Forces in Vehicle Dynamics

Wheel-rail forces are functions of at least four independent variables (multi-dimensional problem):

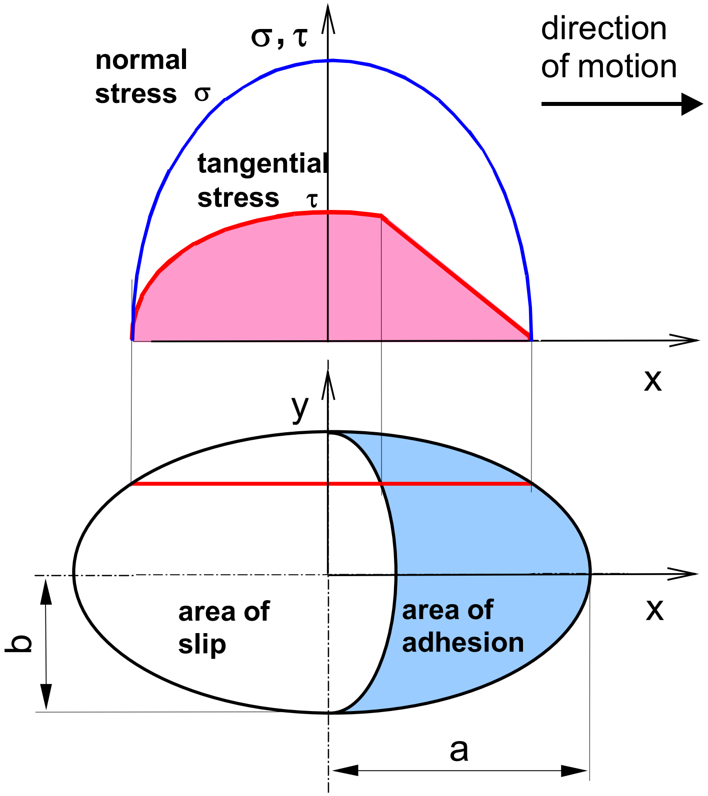
$$F_x, F_y = f\,(\underbrace{s_x, s_y, \omega}_{\text{creepages}}, \underset{\searrow\ \text{shape of the contact area}}{a/b}, Q, f)$$

The calculation is repeated many times for each wheel in each integration step

➔ the calculation time is very important

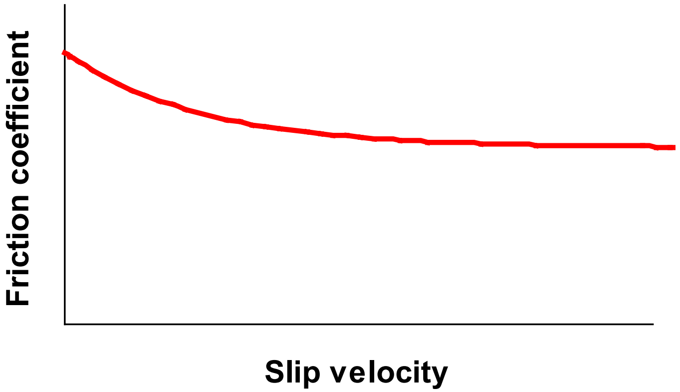
A Time-Saving Method for Calculation of Creep Forces in Multi-body Simulations

- Compromise between calculation time and necessary accuracy
- Magnitude of the resultant creep force as integration of the shear stress distribution
- Effect of spin included - based on integration of tangential stress distribution caused by pure spin and on Kalker's results
- Simple algorithm - no discretisation or iteration loops necessary
- Calculation time comparable with saturation functions or look-up tables
- Accuracy comparable with FASTSIM
- Method available in ADAMS/Rail, SIMPACK, GENSYS and used in other tools as well

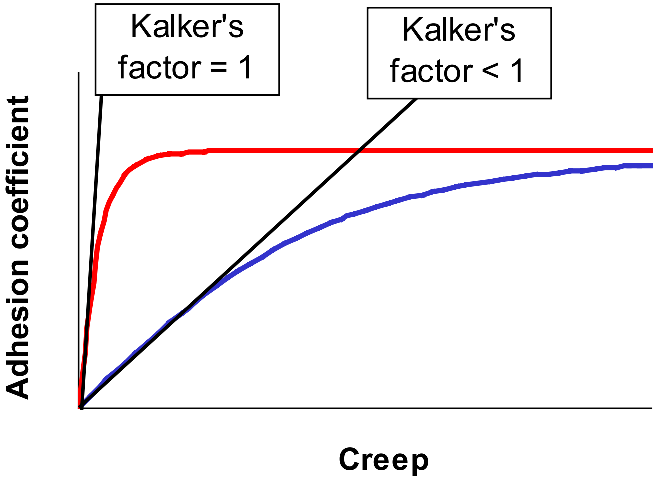


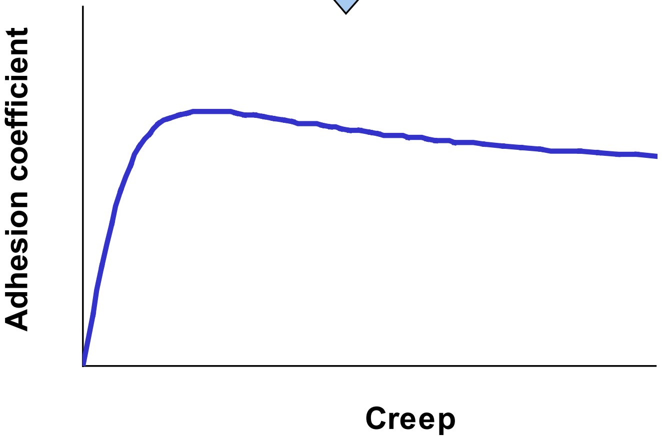
Friction Coefficient Dependent on Slip (Creep) Velocity

- Friction coefficient decreasing with slip velocity



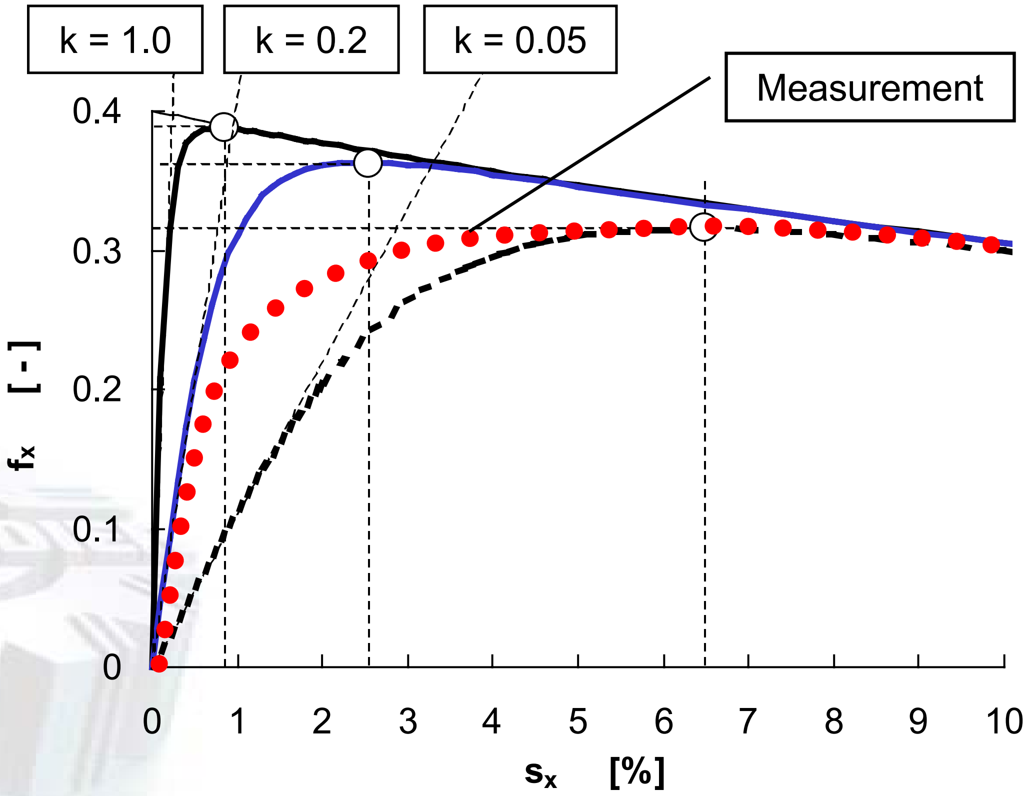
- Reduction of Kalker‘s factor





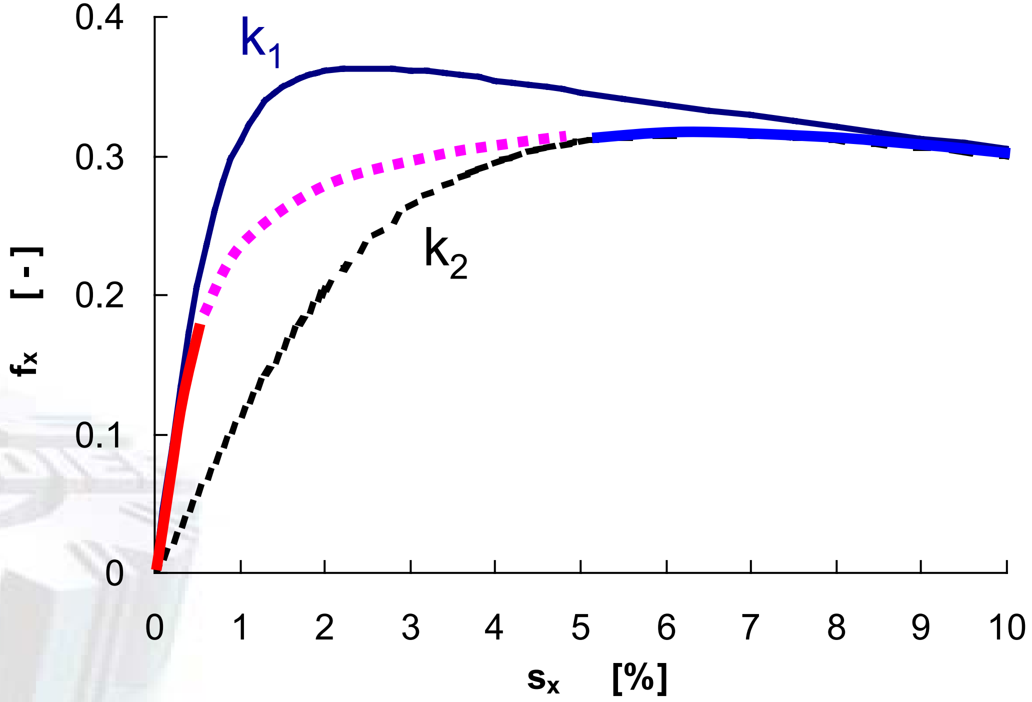
Limitations of the Model with Decreasing Friction Coefficient

- Disagreement mainly for bad adhesion conditions (contaminated or wet rail)



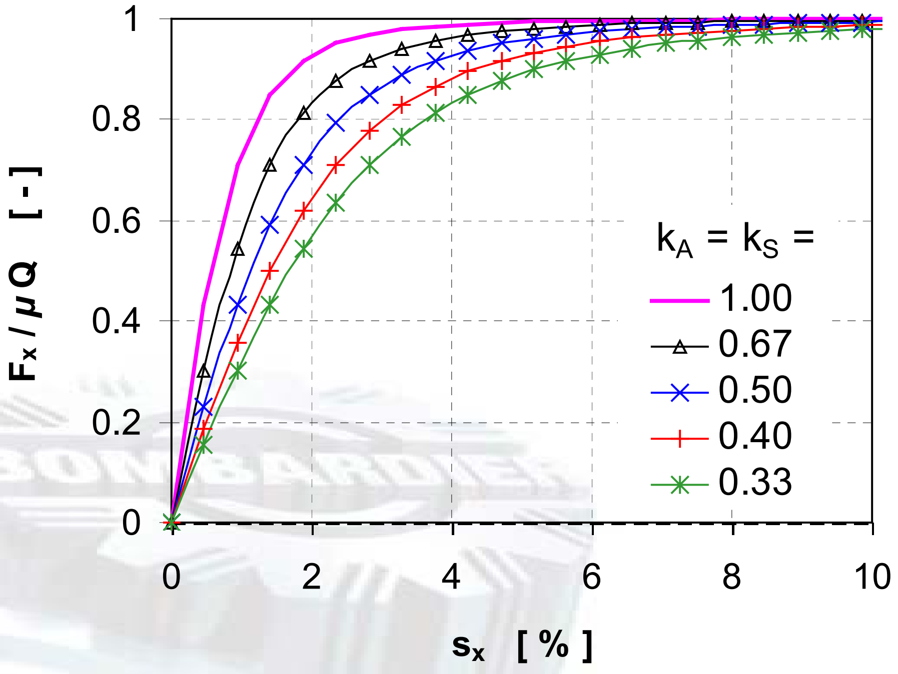
Principle of the Extended Model for Large Creep

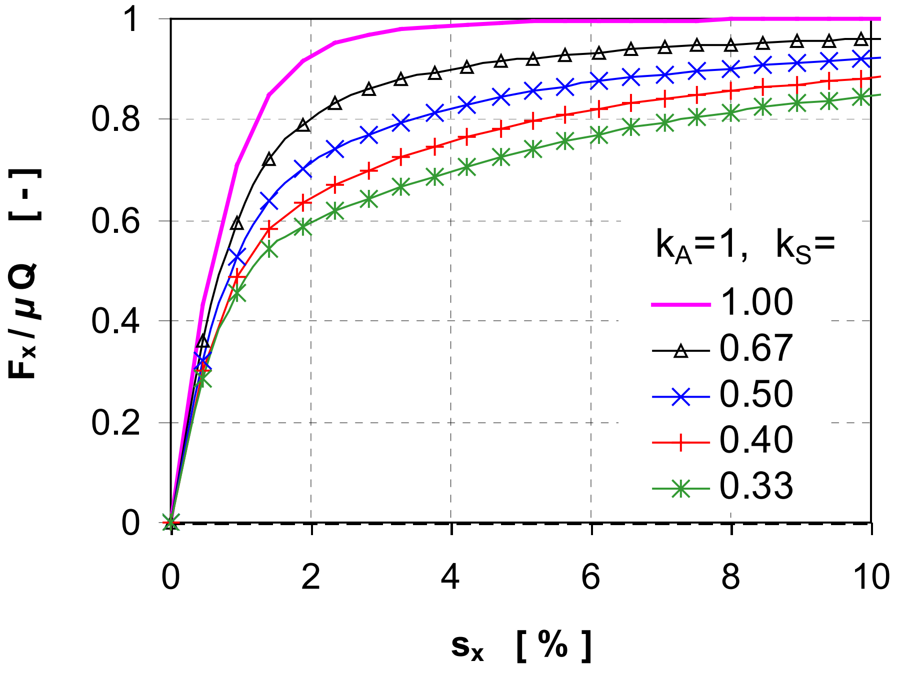
- Decrease of shear stiffness with increasing creep
- Modelled by two reduction factors



Extended Model for Large Creep Applications

- Different reduction factors k_A in the area of adhesion and k_S in the area of slip

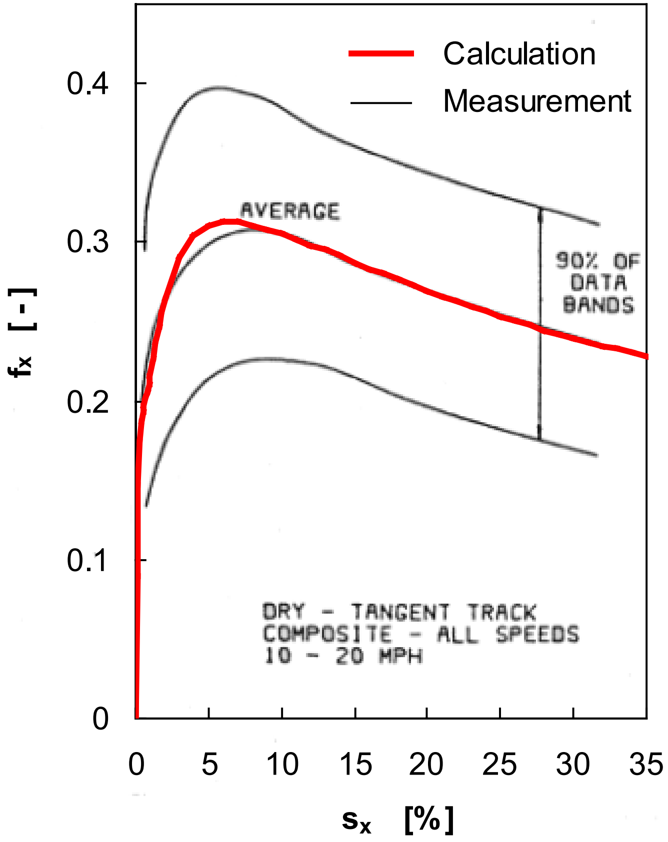




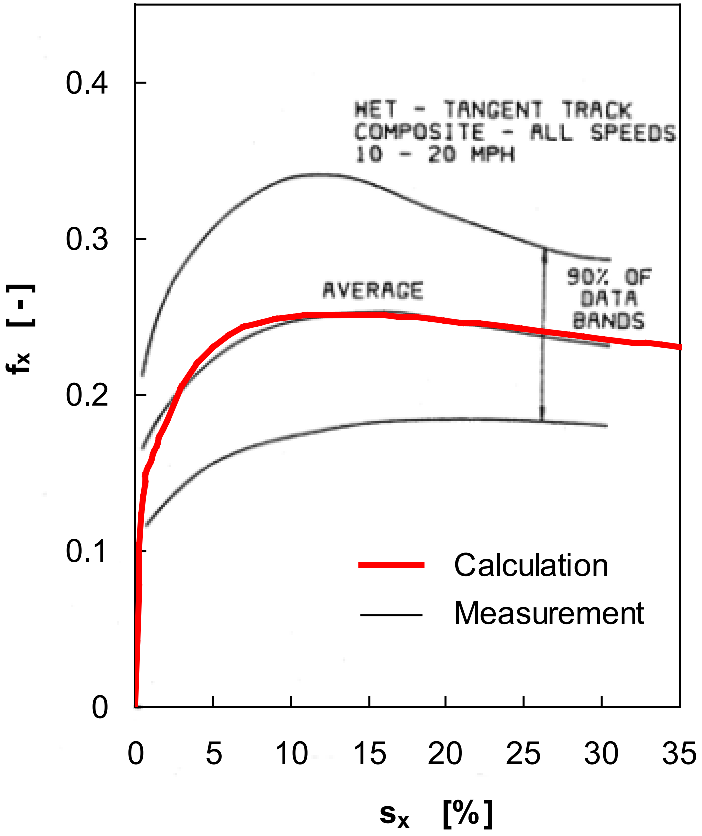
Parameter Identification from Measurements

- Measurements with GM Locomotive SD 45X
  (Logston-Itami, USA, 1980)

Dry rail

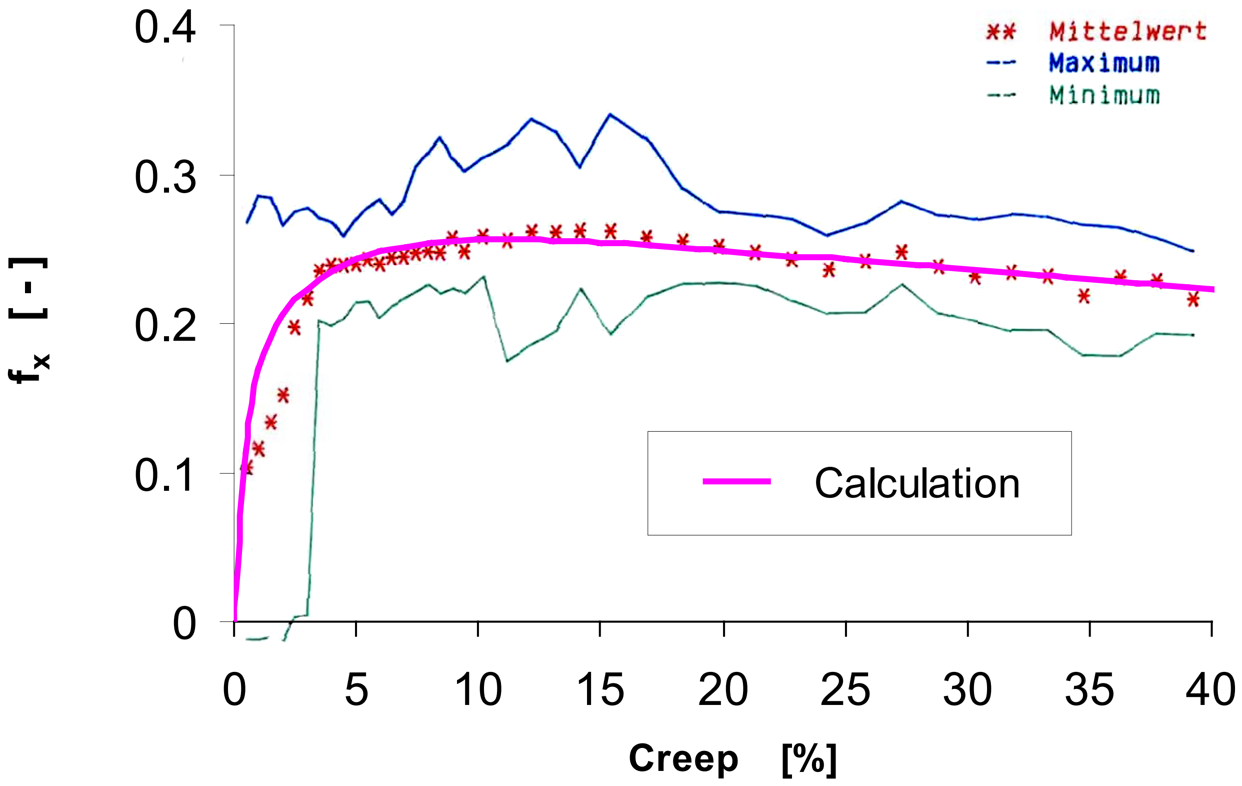


Wet rail



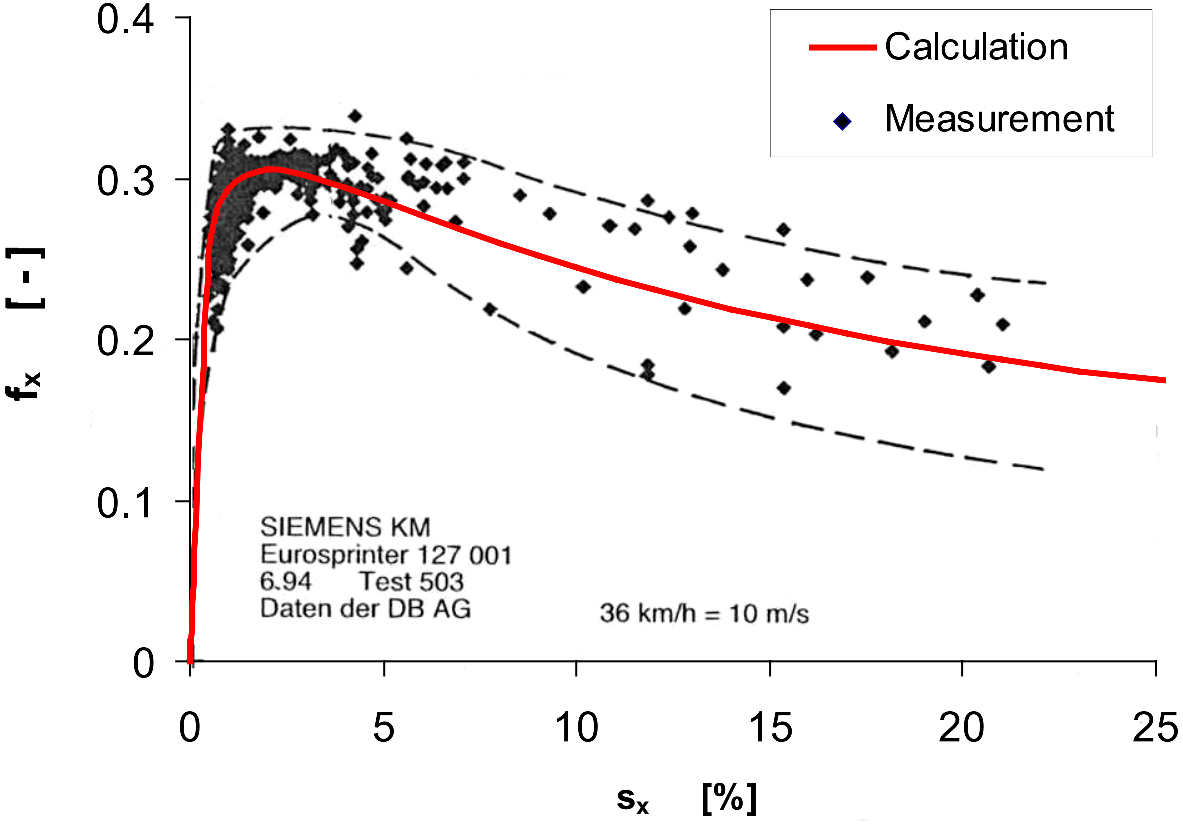
Parameter Identification from Measurements

- Measurements with Bombardier Locomotive SBB 460, watered rails
  (Switzerland, 1992)



Parameter Identification from Measurements

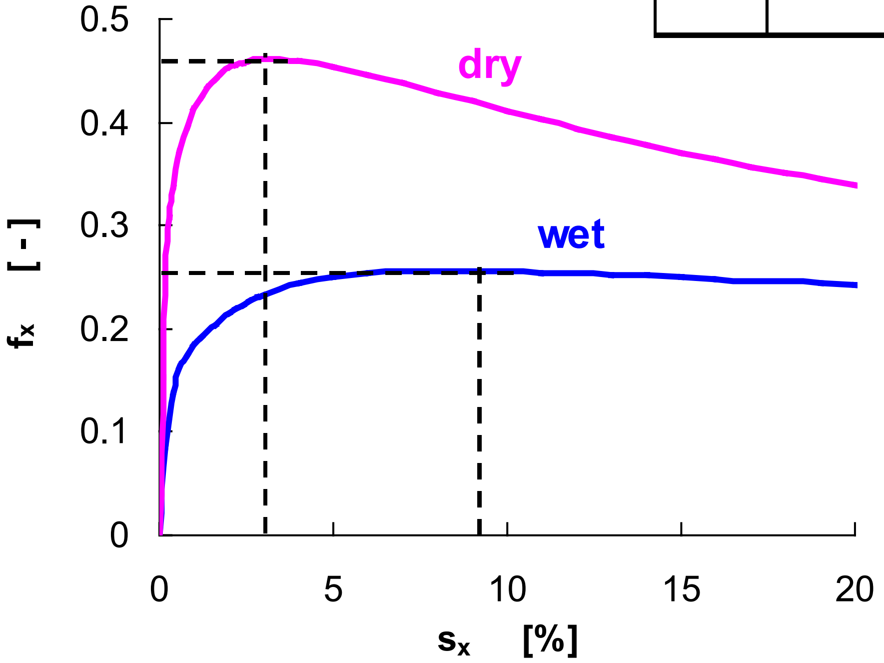
- Measurement with Siemens Locomotive Eurosprinter (DB 127), dry rails
  (Engel -Beck-Alders, Germany, 1998)



Typical Parameters for Real Wheel-Rail Contact

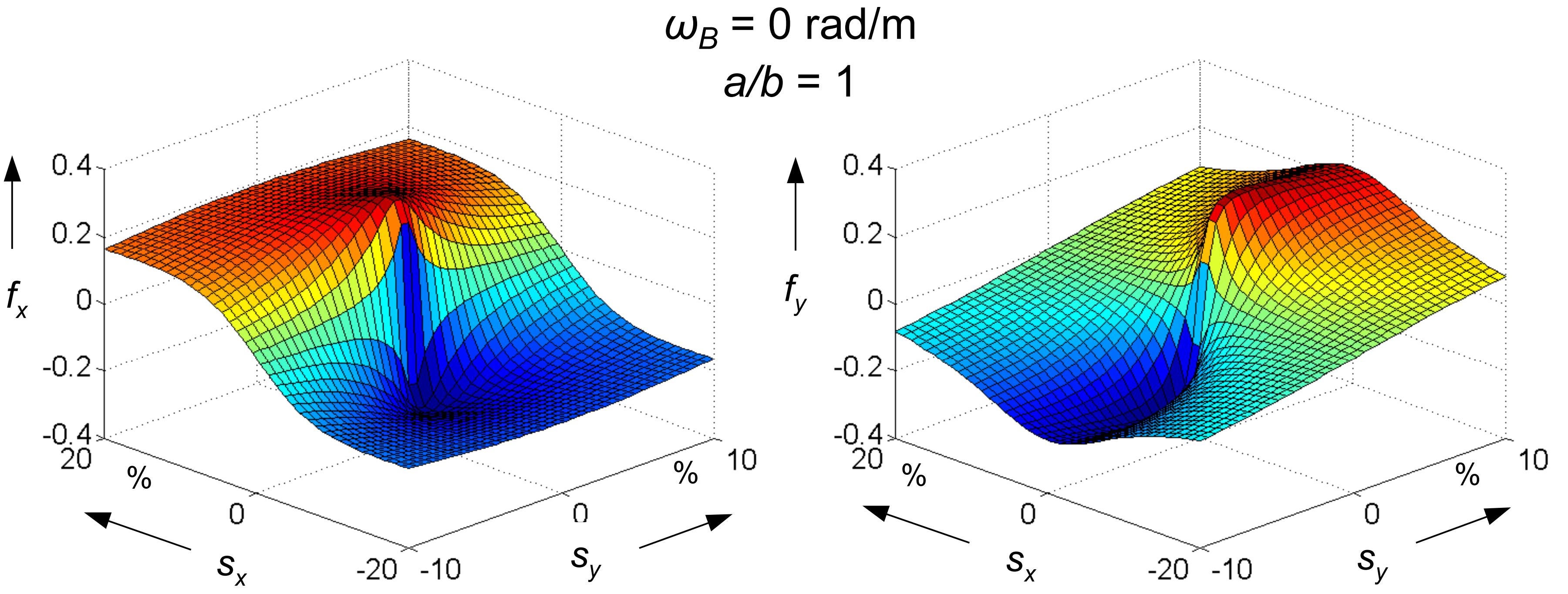
- Three additional parameters :

	Wheel-rail conditions	dry	wet
Modelparameter	k_A	1.00	0.30
	k_S	0.40	0.10
	μ_0	0.55	0.30
	A	0.40	0.40
	B (s/m)	0.60	0.20



Extended Model for Large Creep Applications (1)

- Influence of longitudinal, lateral, spin creepages and the shape of the contact ellipse considered



ω_B = 0 rad/m

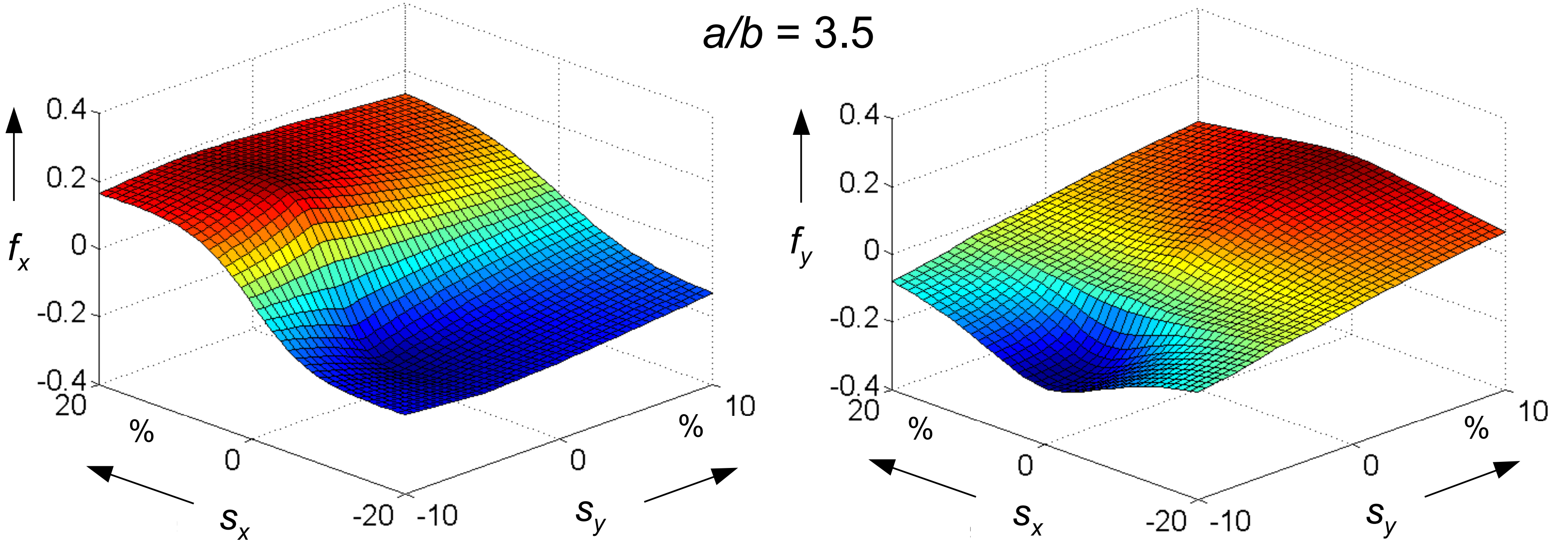
a/b = 1

Extended Model for Large Creep Applications (2)

- Influence of longitudinal, lateral, spin creepages and the shape of the contact ellipse considered

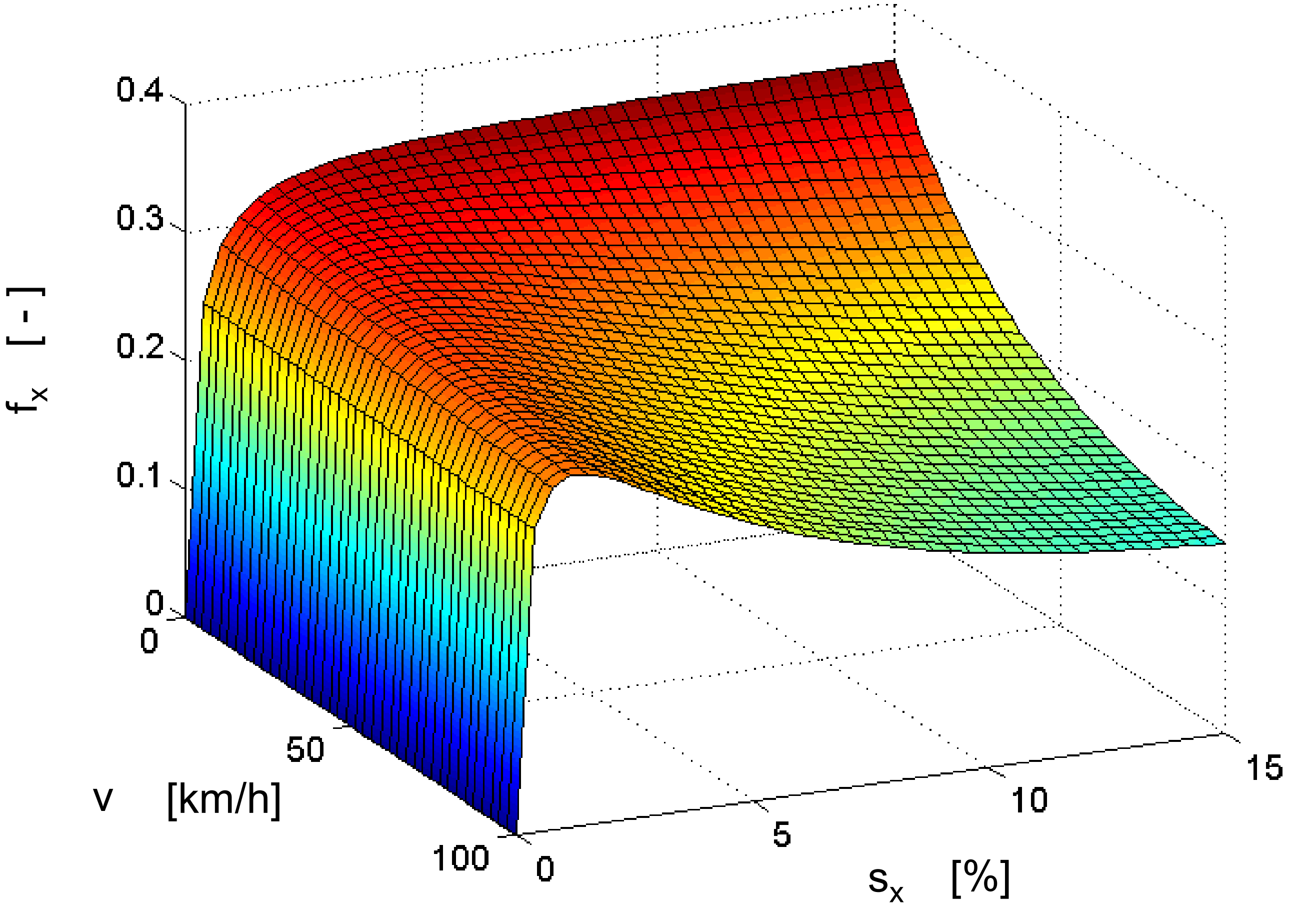
ω_B = 10 rad/m

a/b = 3.5

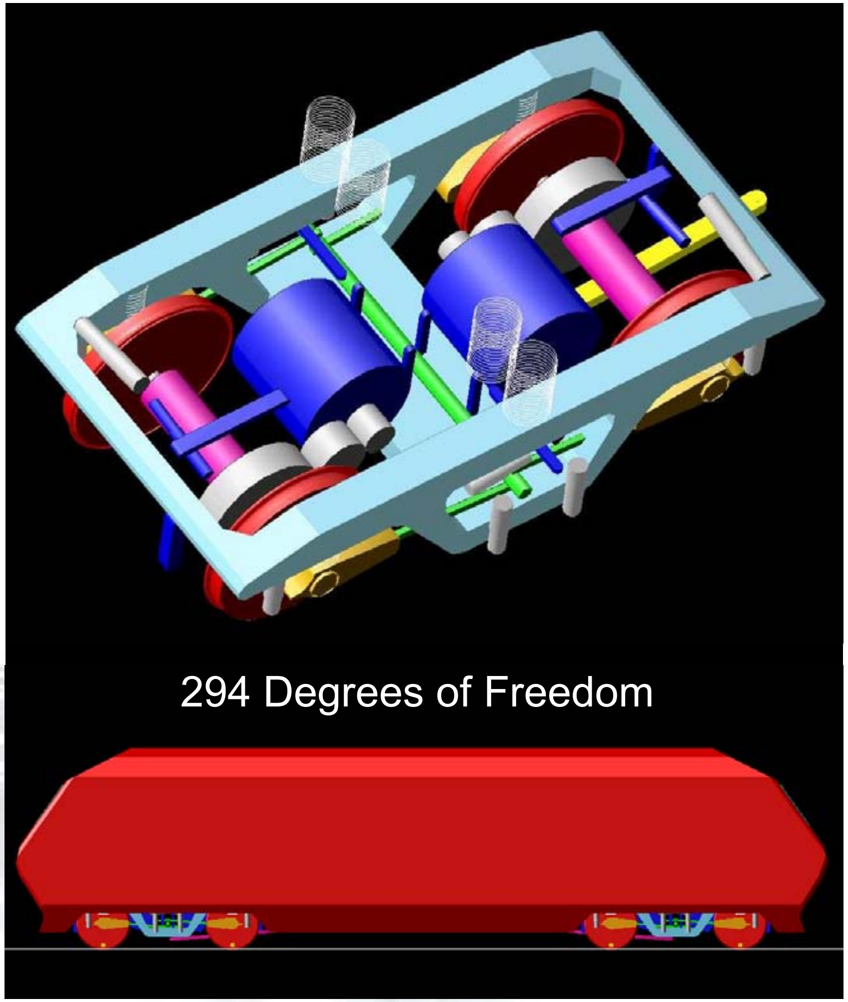


Extended Model for Large Creep Applications (3)

- Influence of vehicle speed

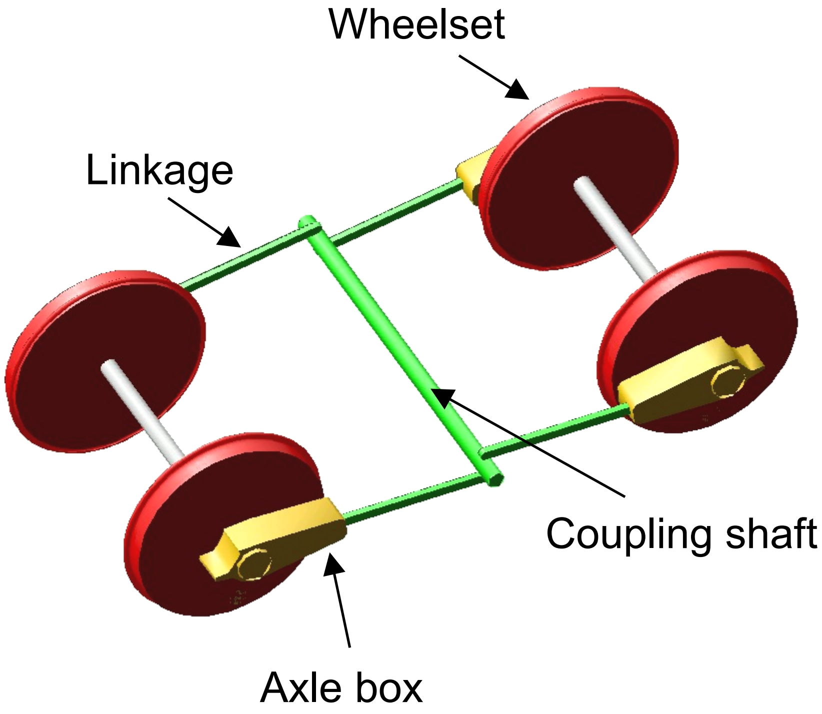


Influence of Tractive Force on the Self-Steering Model of Locomotive SBB 460 (ADAMS/Rail)



294 Degrees of Freedom

Mechanism
of Wheelset Coupling:



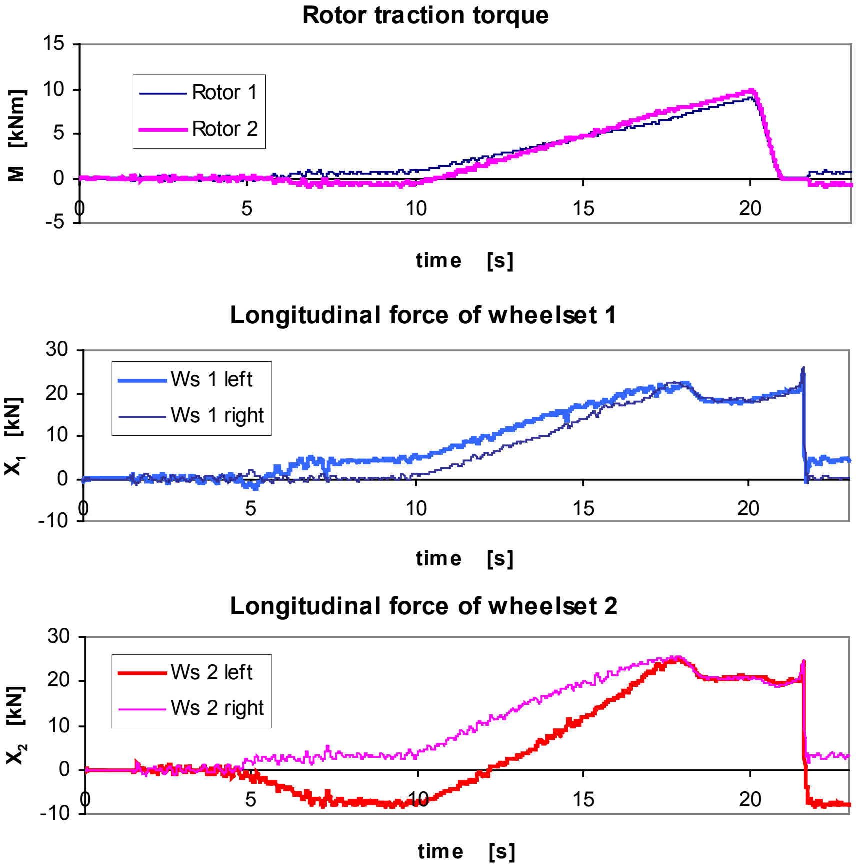
Simulation of Adhesion Test with Locomotive SBB 460

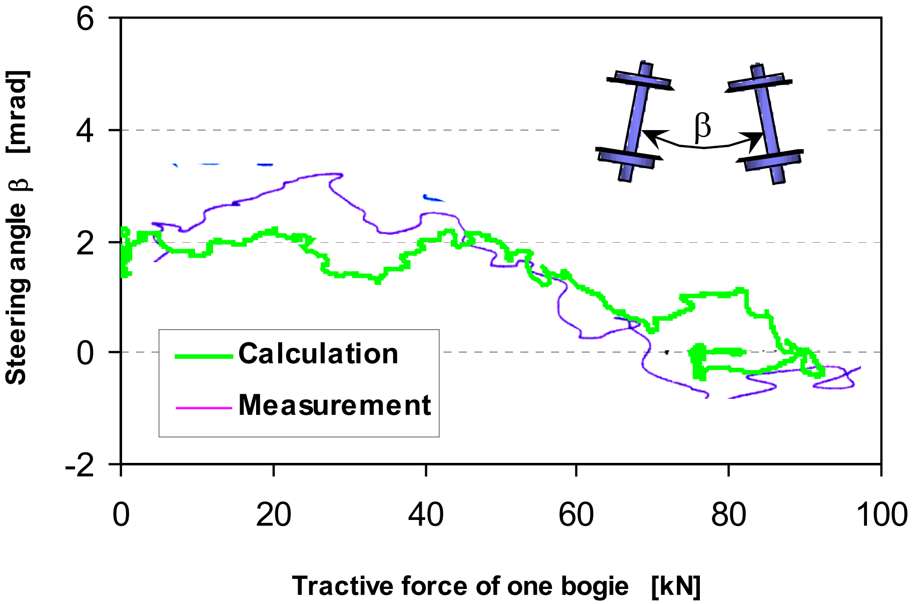
- Output time plots - leading bogie

Curve: R = 400 m

Vehicle speed: V = 70 km/h

Rail conditions: wet

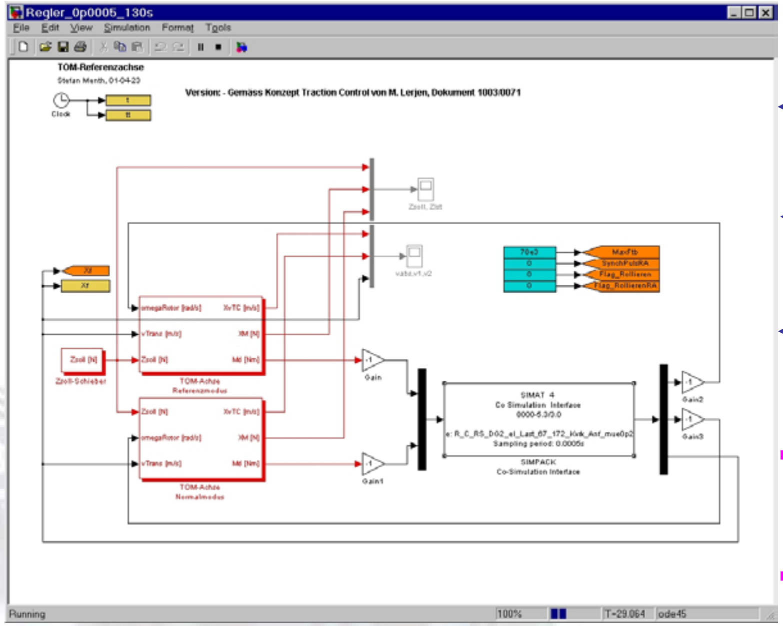




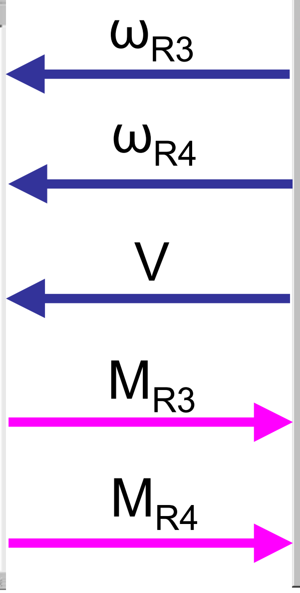
Co-Simulation of Vehicle Dynamics and Traction Control

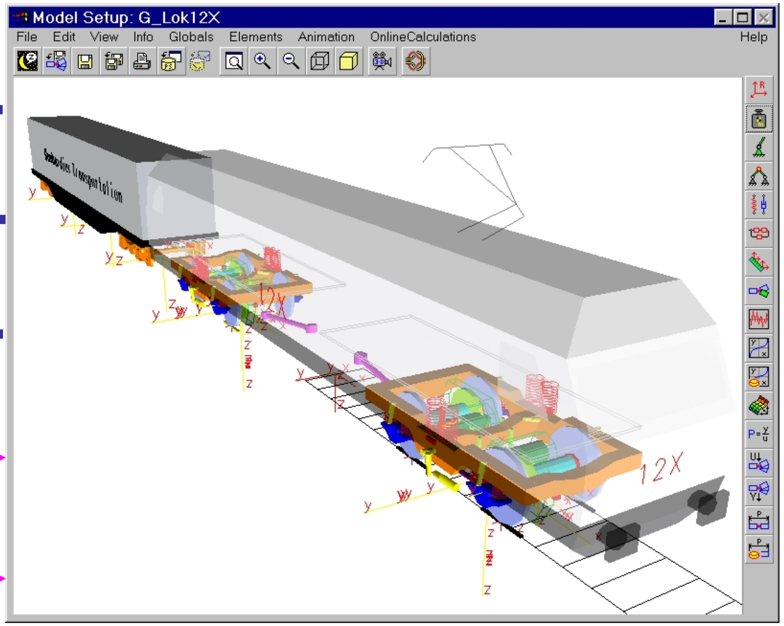
Traction Controller
(MATLAB-SIMULINK)

Vehicle Model
(SIMPACK)



Version: - Gemäss Konzept Traction Control von M. Lerjen, Dokument 1003/0071





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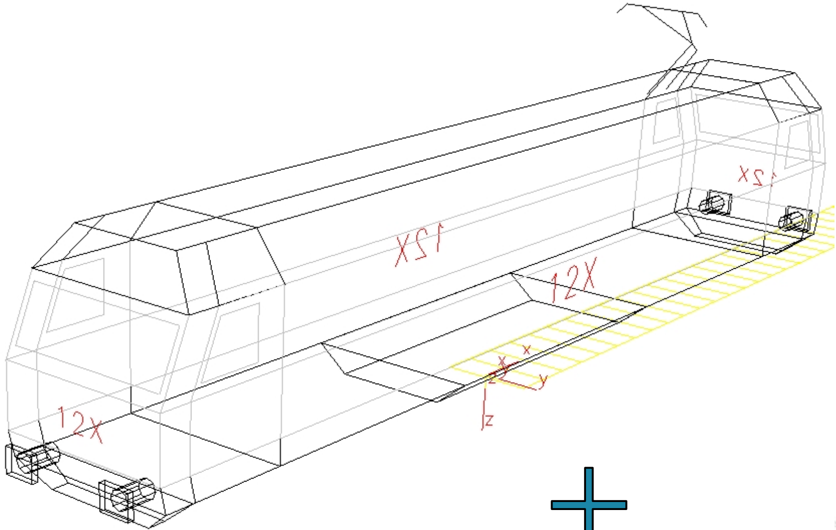
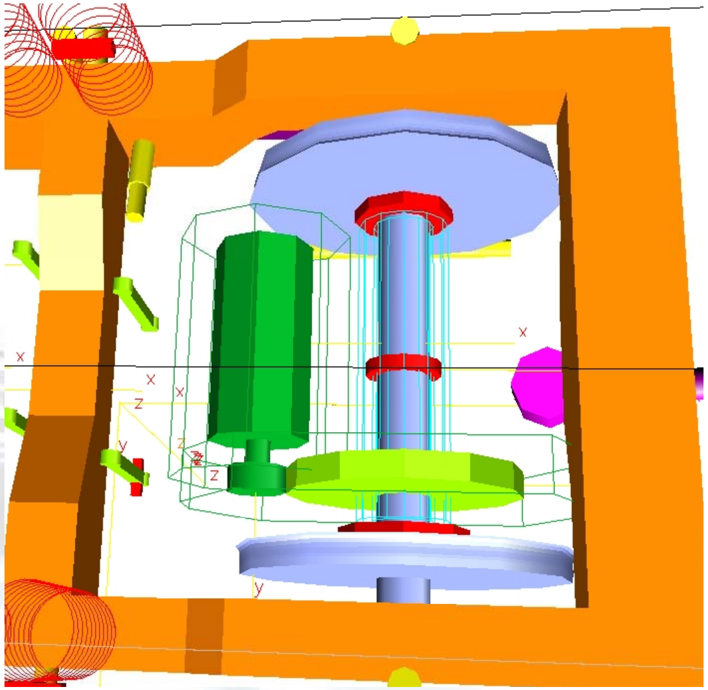
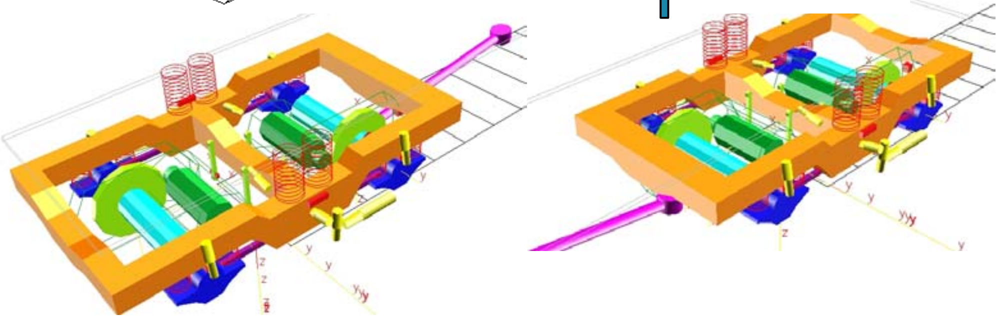
Vehicle Model:
Test Locomotive DB 128 (12X)

- Extended multi-body model
  - Vehicle model
  - Traction chain with torsionaly elastic wheelset

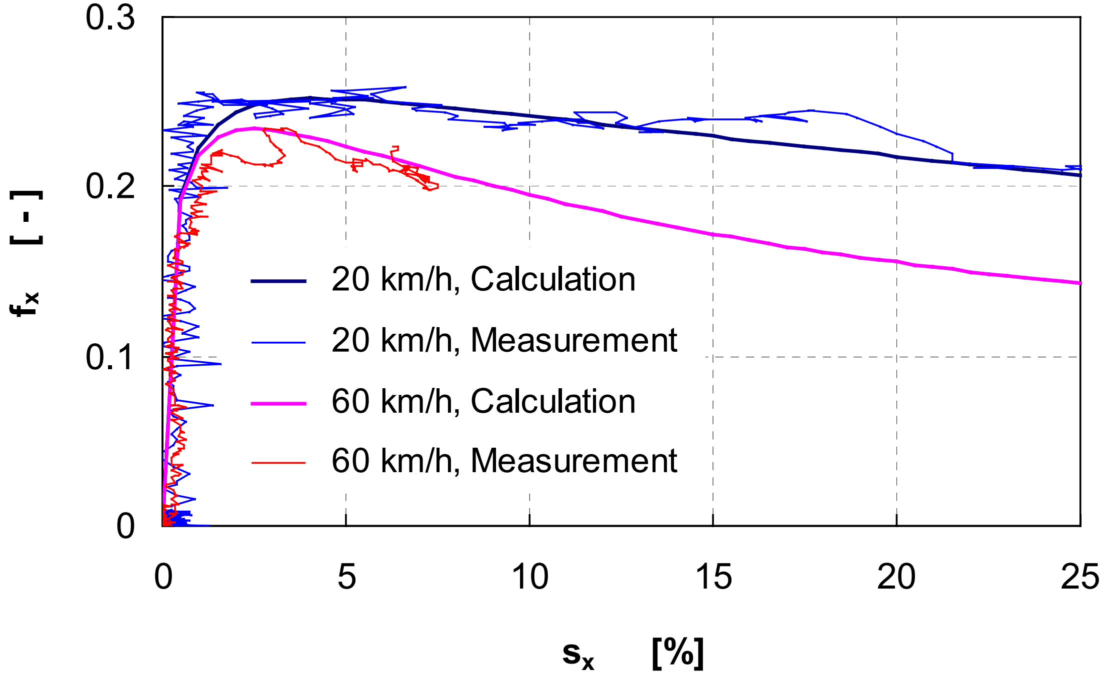






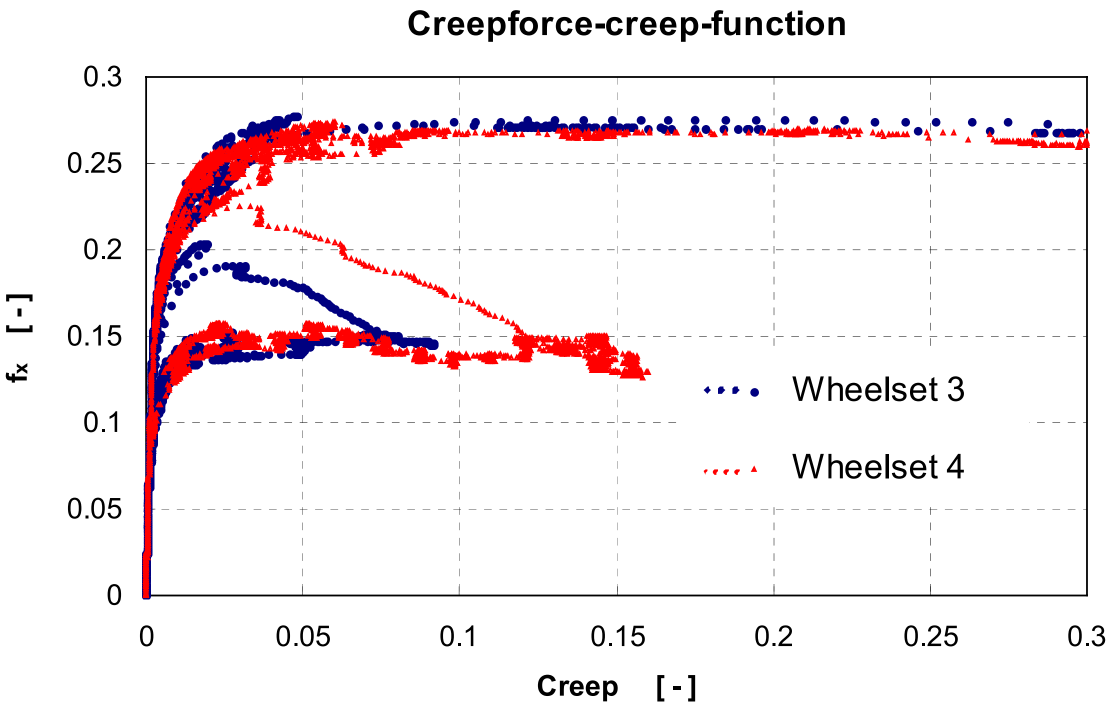
Parameter Identification of Creep Force Model from Measured Creeforce-Creep-Functions

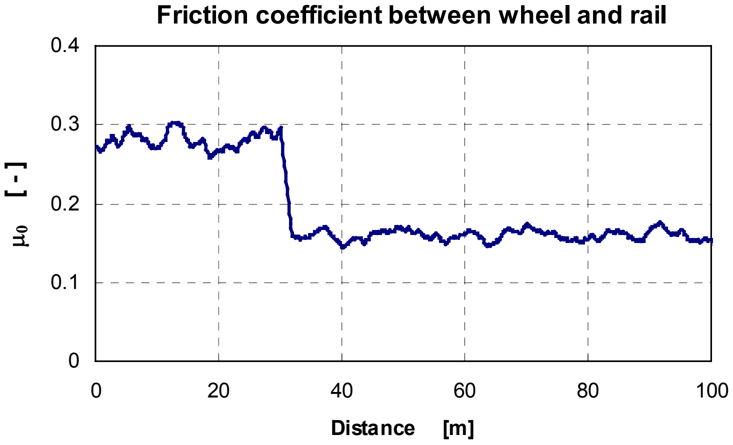
- One parameter set considers the influence of :
  - Vehicle speed
  - Longitudinal creep
  - Lateral creep
  - Spin
  - Contact geometry
  - Normal force

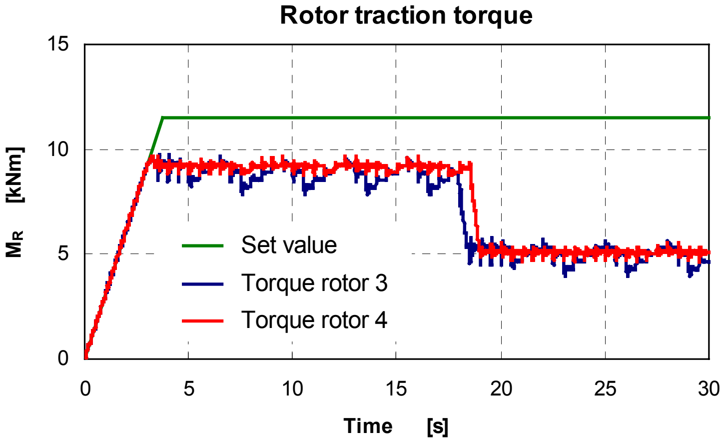


Reaction of Traction Control on Sudden Worsening of Adhesion Conditions

- Starting on straight track
- Sudden decrease of friction coefficient



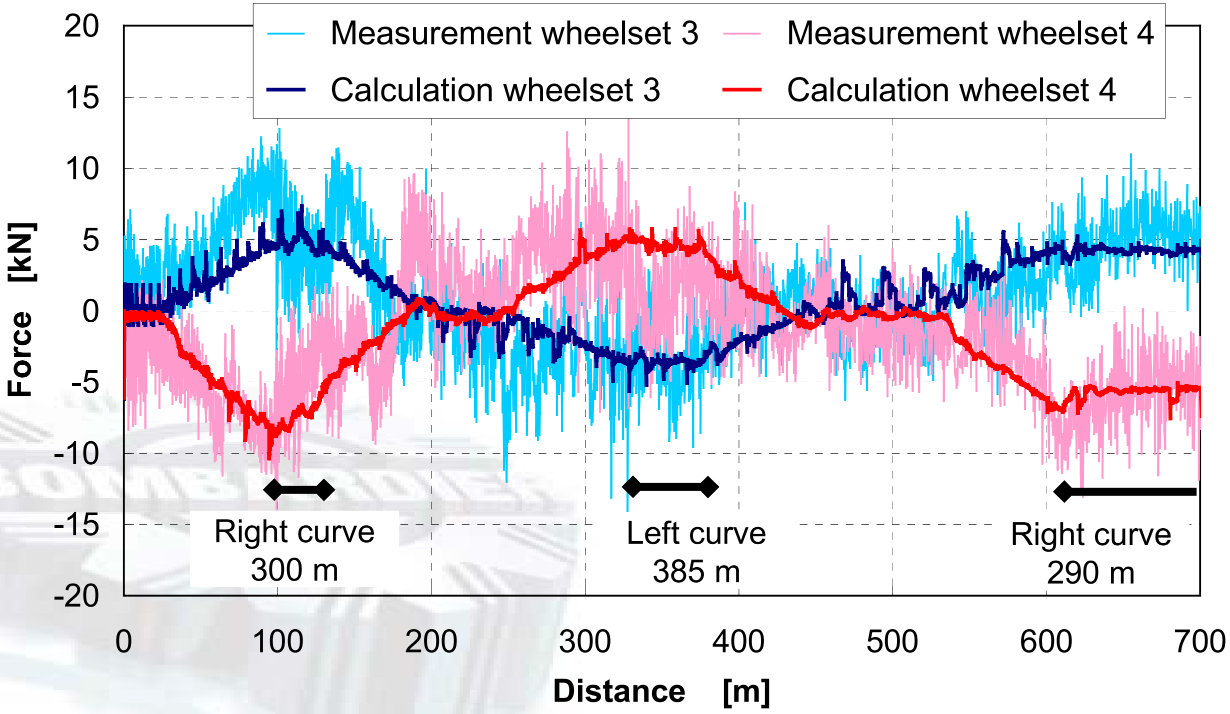


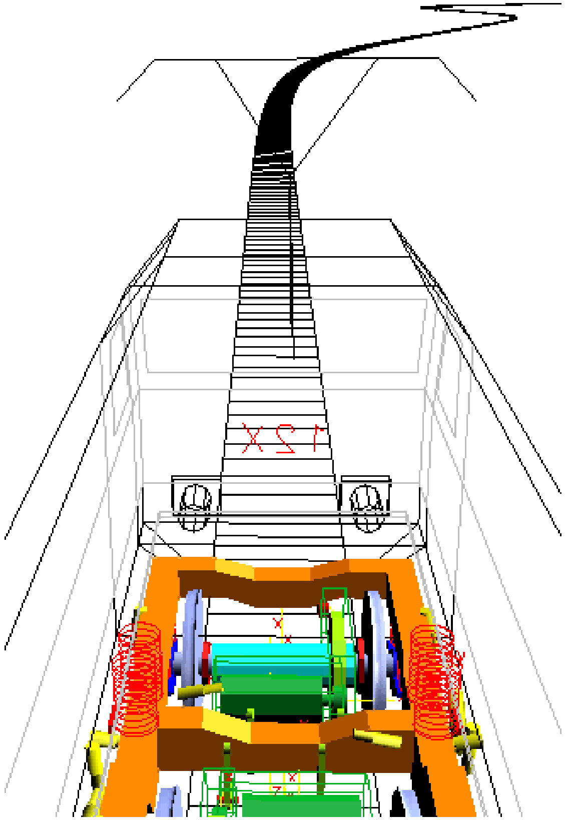


Comparison Calculation - Measurement

- Starting and acceleration of a test composition on curved sloping track (Kanderviadukt, Switzerland, August 2001)

Longitudinal guiding force
(Difference left - right)





Conclusions

- The proposed method enables computer simulations of complex vehicle system dynamics including running and traction dynamics
- Influence of speed, shape of the contact ellipse, longitudinal, lateral and spin creep is considered using one parameter set
- The method can be used to model the creep forces based on the measured creepforce-creep-functions
- If no measurements are available, the parameters recommended for typical wheel-rail contact conditions can be used in engineering applications
- The method was used in complex simulations and validated by comparisons with measurements