Influence of Locomotive Tractive Effort on the Forces between Wheel and Rail

Oldrich POLACH

Adtranz

DaimlerChrysler Rail Systems (Switzerland) Ltd
Winterthur, Switzerland

Contents

- Calculation of wheel-rail forces in railway vehicle dynamics
- Differences in the calculation of wheel-rail forces in vehicle dynamics and in drive dynamics
- Model of wheel-rail forces suitable for computer simulation of vehicle and drive dynamics interaction
- Influence of tractive effort on the wheel-rail forces during curving
- Co-simulation of vehicle dynamics and traction control
- Conclusions

Calculation of Forces Between Wheel and Rail in Vehicle Dynamics

ADtranz
a~áãäÉê `ÜêóëäÉê=o~áä=póëíÉãë

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

$$F_x, F_y = f\,(\underbrace{s_x, s_y, \omega}_{\text{creepages}}, a/b, Q, f)$$

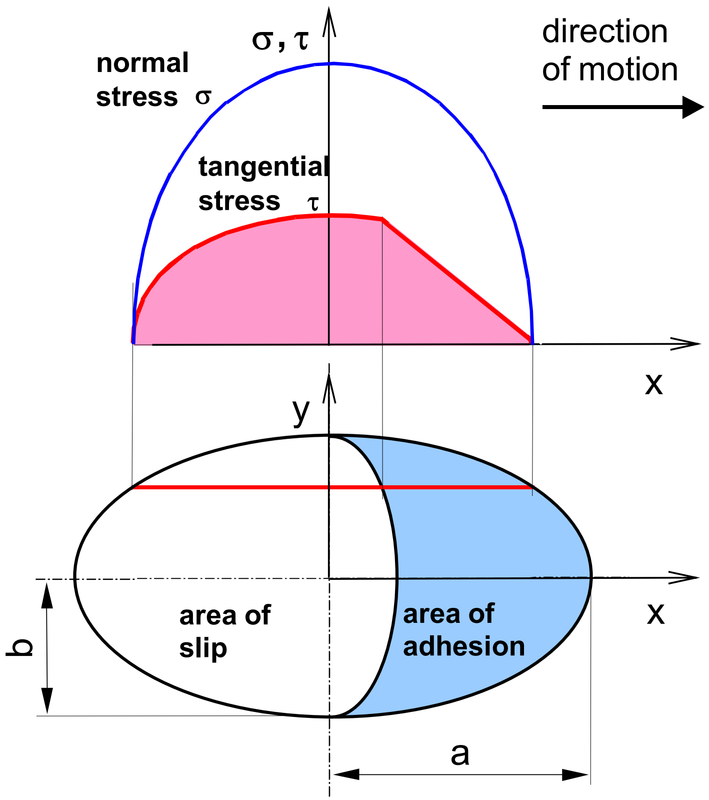
form of the contact area

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

➔ the calculation time is very important

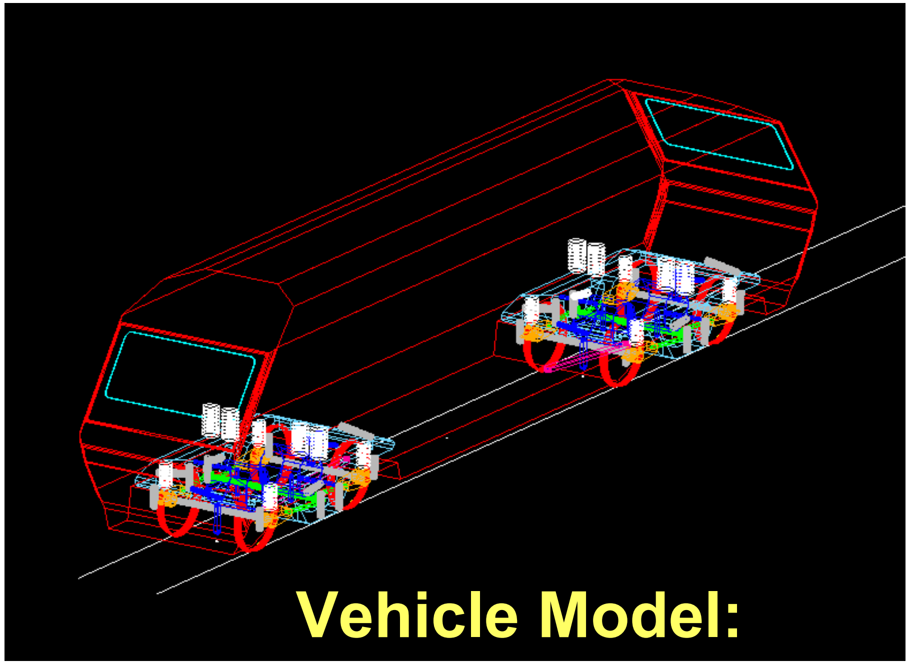
A Time Saving Method of Wheel-Rail Forces Calculation

- Compromise between calculation time and necessary accuracy
- Spin taken into account
- Calculation time comparable with saturation functions or look-up tables
- Pre-calculation superfluous
- Accuracy comparable with FASTSIM or look-up tables
- Principle and computer code published at the 16th IAVSD Symposium, Pretoria 1999



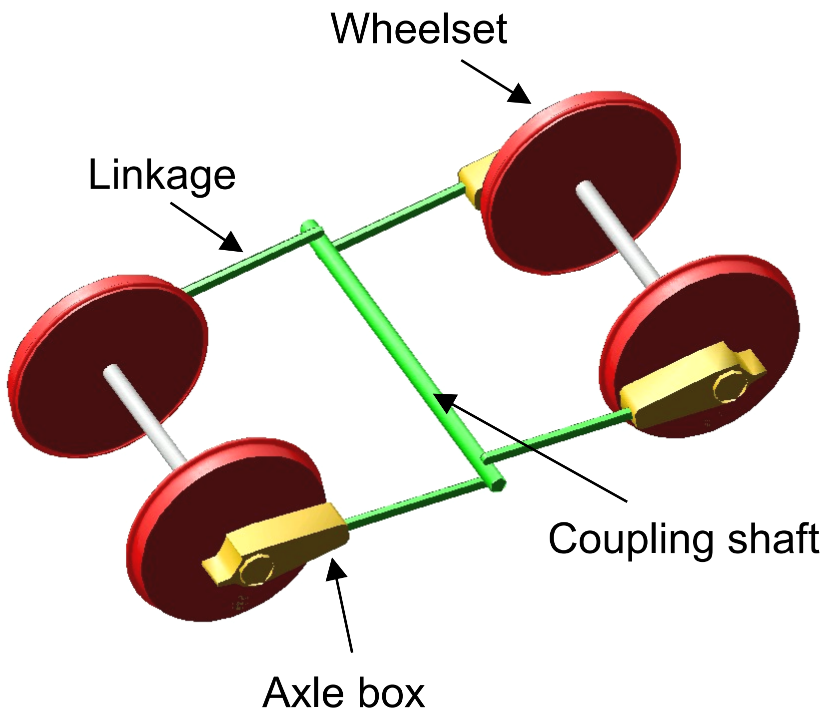
Comparison of Simulation and Measurement
ADAMS/Rail Model of Locomotive SBB 460

ADtranz
a~ãäÉê`ÜêóëäÉê-o~ää-póëíÉãë



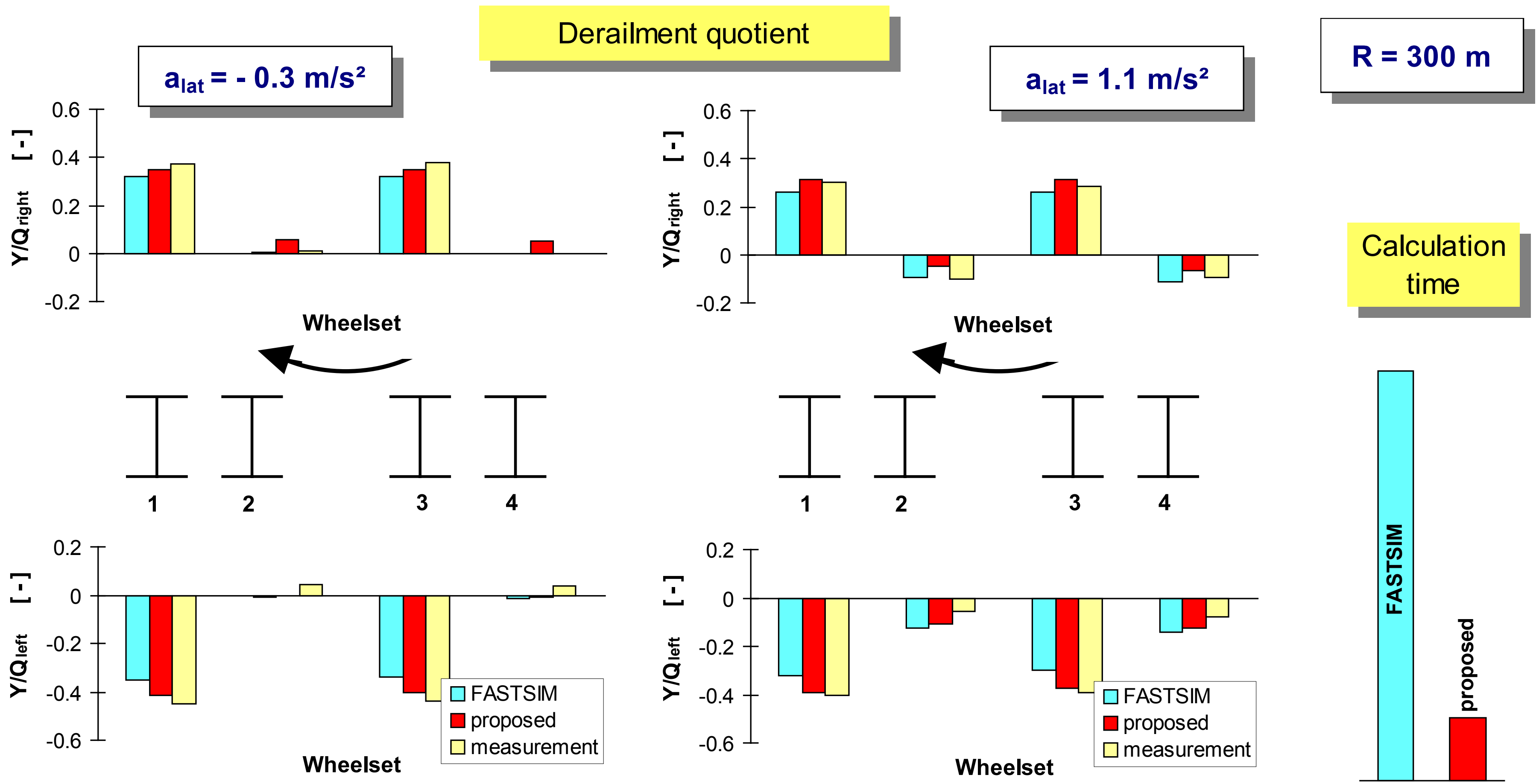
- 51 rigid bodies
- 84 bushings
- 4 bump-stops
- 24 dampers

Mechanism
of Wheelset Coupling:



Comparison of Simulation and Measurement Results

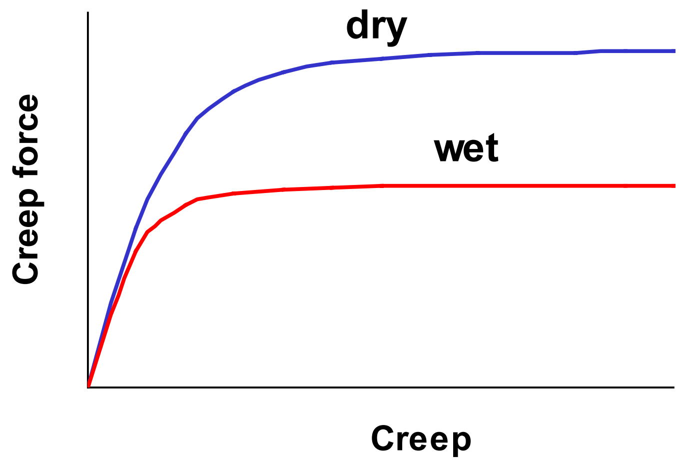
ADtranz



Differences of Creep-Force Functions in Vehicle Dynamics and Drive Dynamics

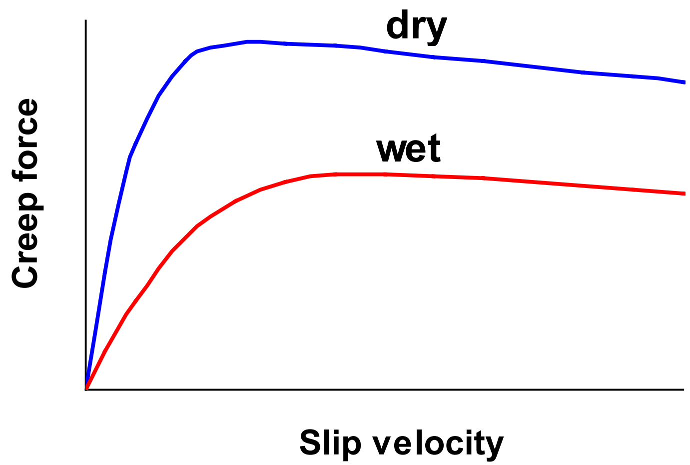
ADtranz
a~ã ãÉê`ÜêóëÉê-o~ä-póëíÉãë

Vehicle Dynamics



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

Drive Dynamics

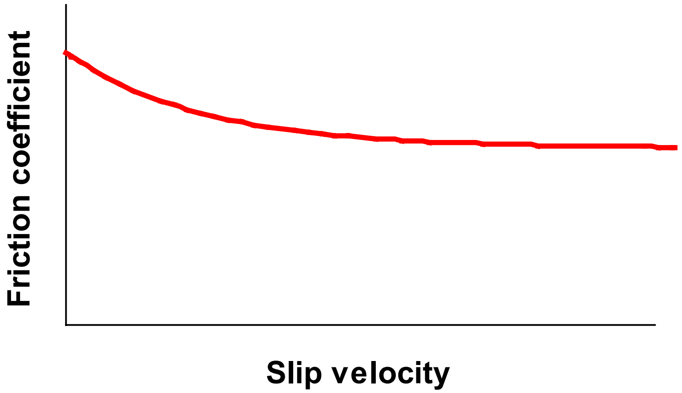


- Necessary for drive dynamics (large creep - slip)
- Usually used only for longitudinal direction
- Function of slip velocity

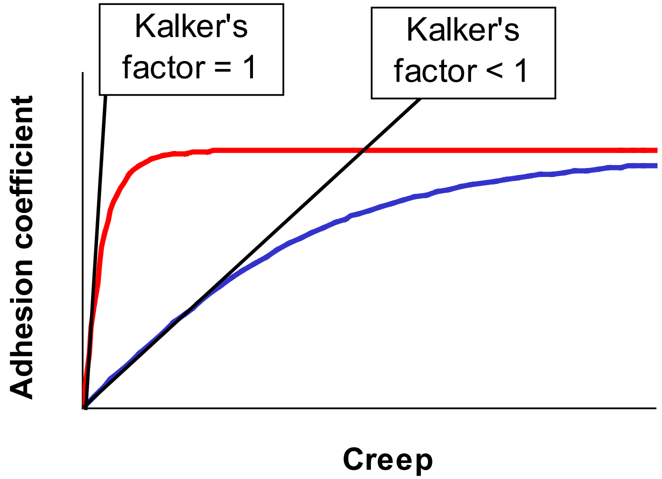
Wheel-Rail Model for Computer Simulation of Vehicle and Drive Dynamics

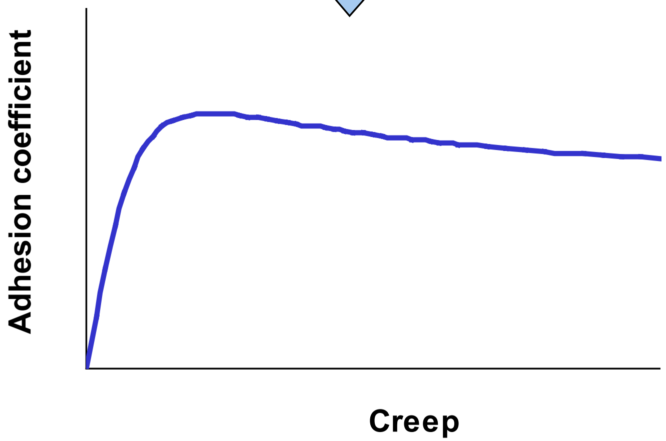
ADtranz
a~áãäÉê`ÜêóëäÉê=o~áä=póëíÉãë

- Friction coefficient decreasing with slip velocity



- Reduction of Kalker‘s factor



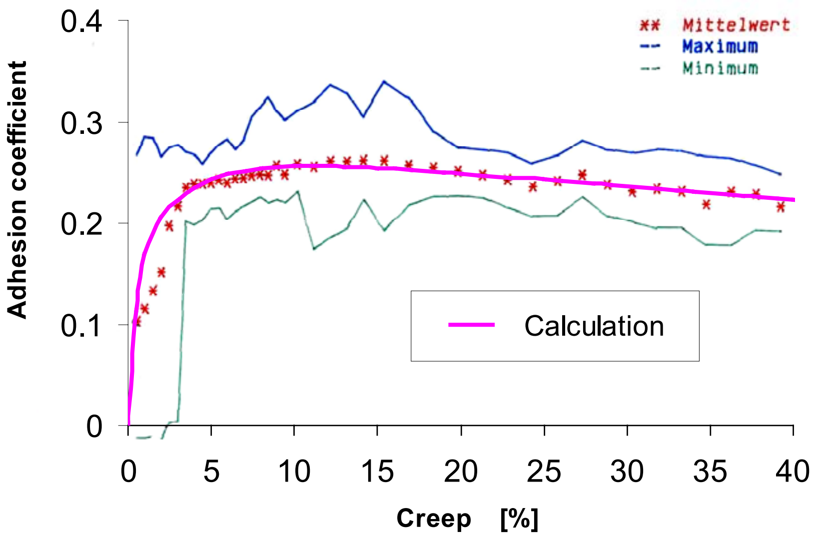


Wheel-Rail Model for Computer Simulation of Vehicle and Drive Dynamics

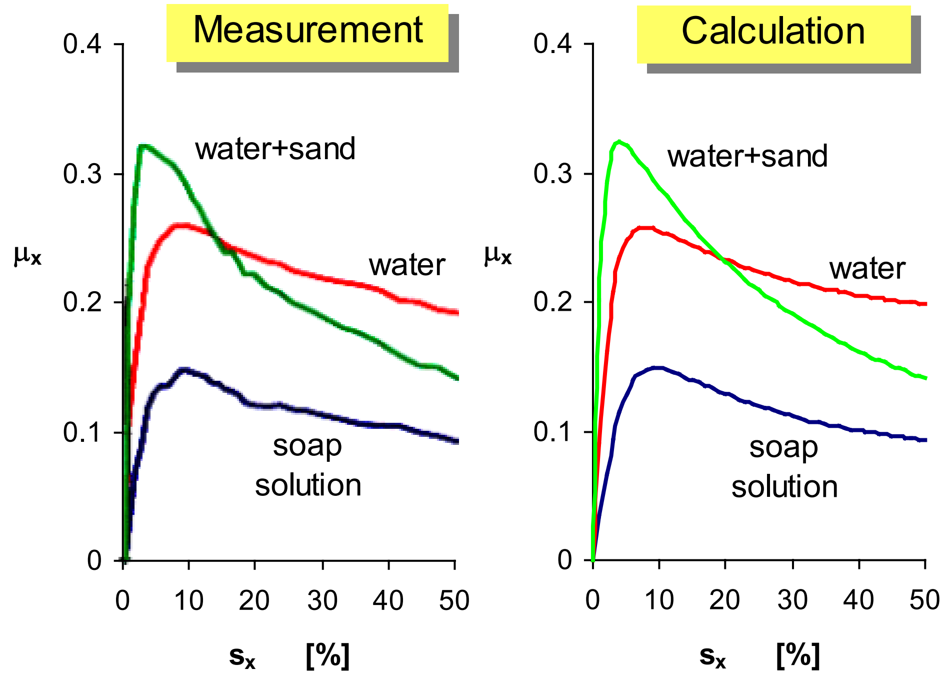
- Modelling of measured creep-force functions
  (Measurement on locomotive SBB 460)

V = 40 km/h, wet

Average curve of 7 measurements



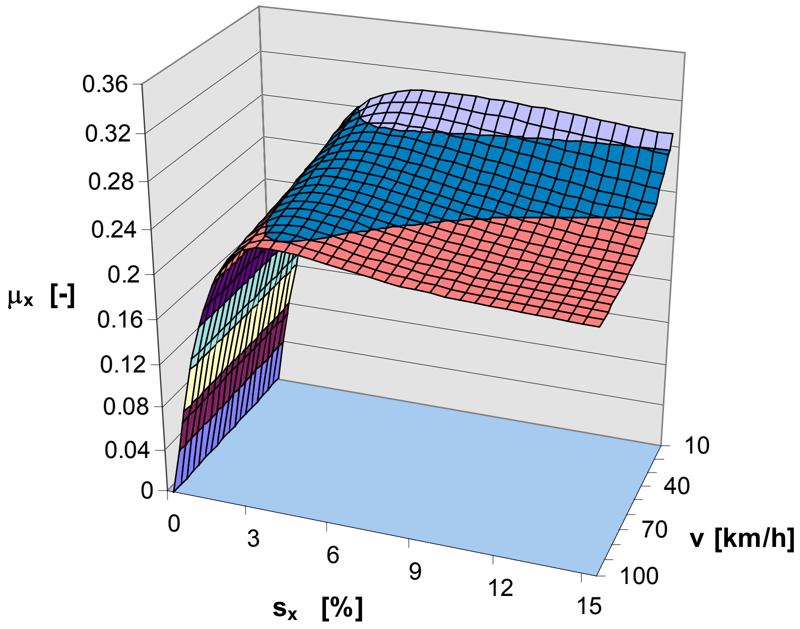
V = 20 km/h

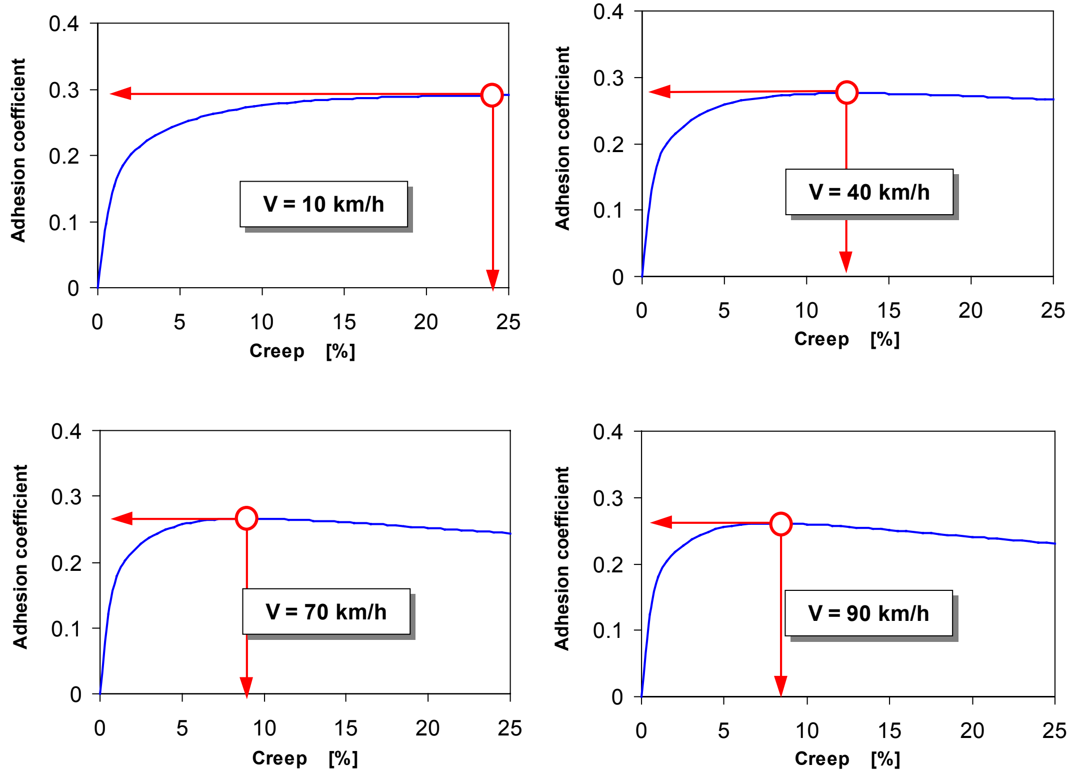


Wheel-Rail Model for Computer Simulation of Vehicle and Drive Dynamics

ADtranz
a~áãäÉê`ÜêóëäÉê=o~áä=póëíÉãë

- Influence of vehicle speed

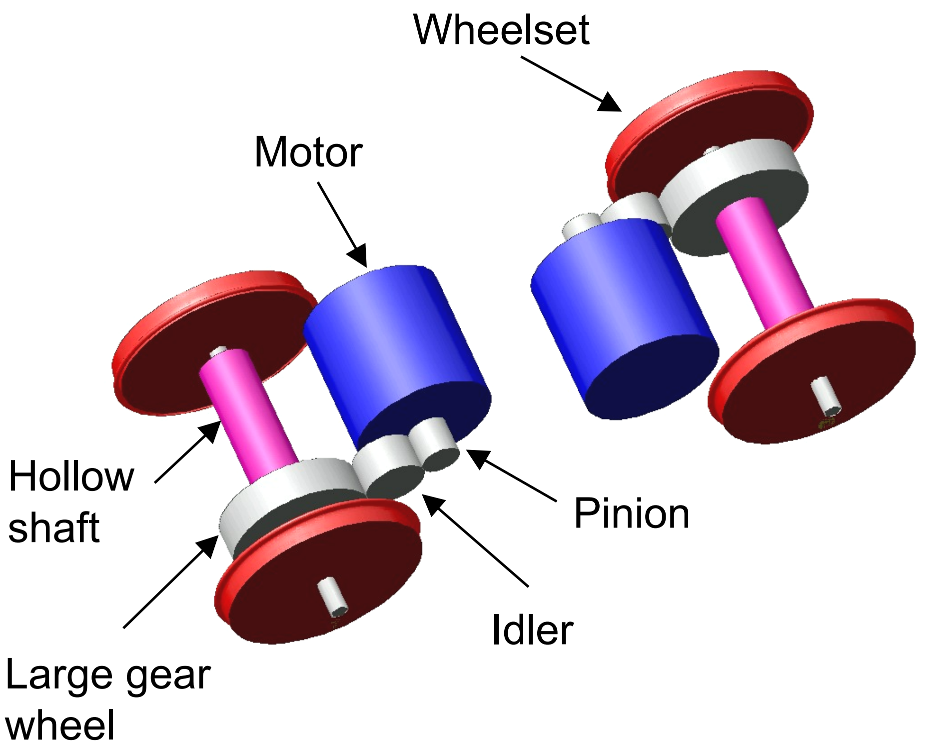


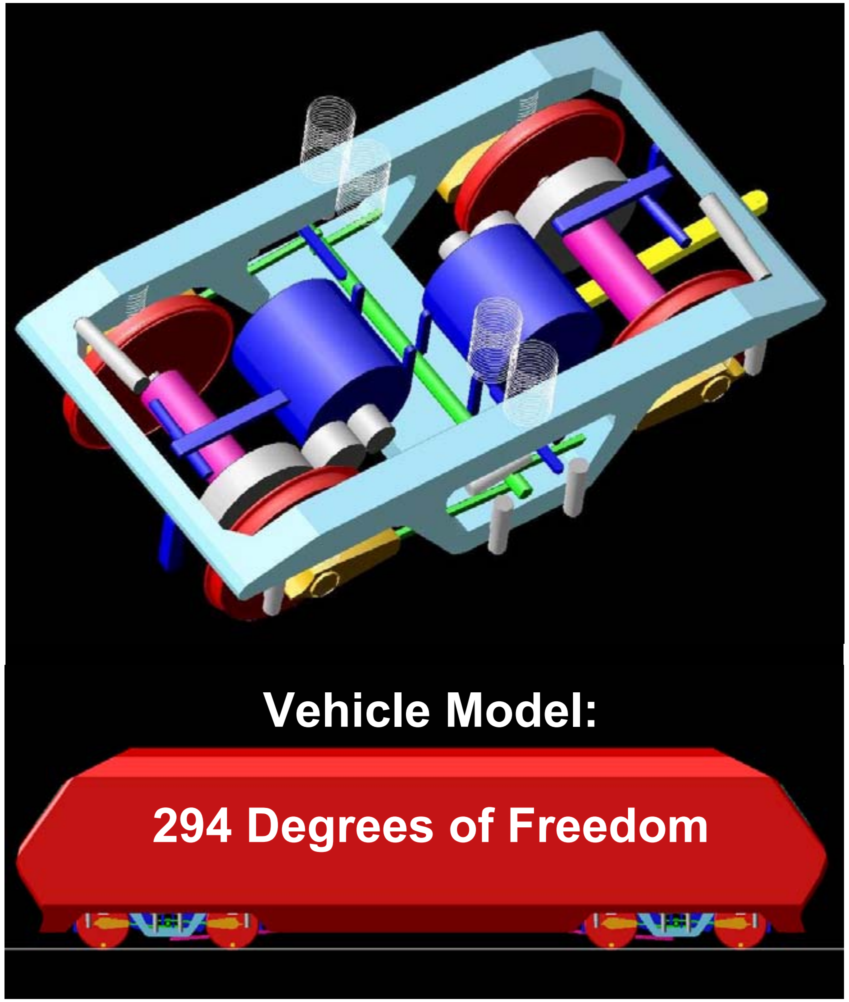


Simulation of Vehicle and Drive Dynamics Model of Loco SBB 460 Including Drive System

ADtranz
a~áãäÉê `ÜêóëäÉê=o~áä=póëíÉãë

Drive System:

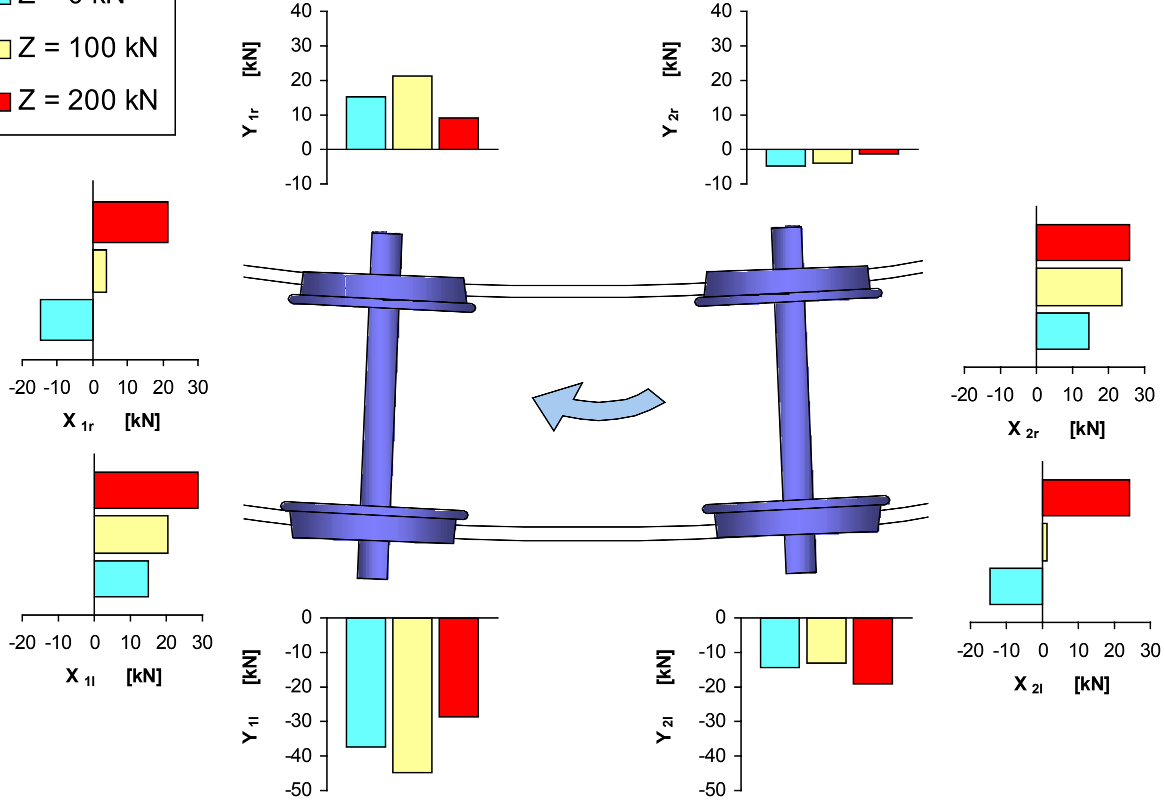




Influence of Locomotive Tractive Effort on the Wheel-Rail Forces in a Curve

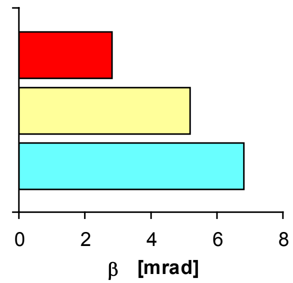
Tractive force:
- Z = 0 kN
- Z = 100 kN
- Z = 200 kN

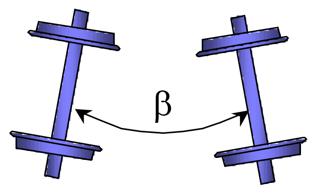
Forces between wheel and rail



R = 300 m, a_{lat} = 1 m/s²
wet condition, friction coefficient function of slip velocity

Steering angle

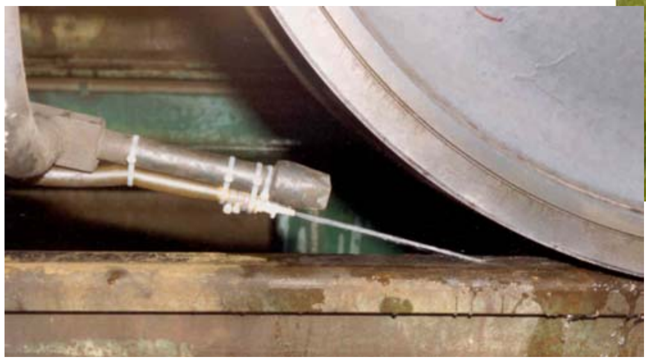




Adhesion Tests with Locomotive SBB 460

ADtranz
a~ä ãäÉê ` ÜêóëäÉê-o~áä-póëíÉ ã ë

- Test composition



Simulation of the Adhesion Test

ADtranz

a~áãäÉê`ÜêóëäÉê=o~áä=póëíÉãë

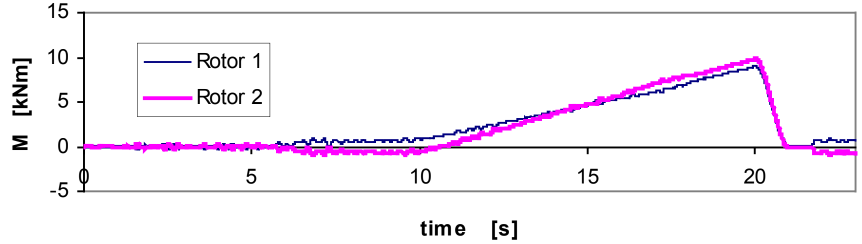
- Time plots of the values on the leading bogie

Curve: R = 400 m

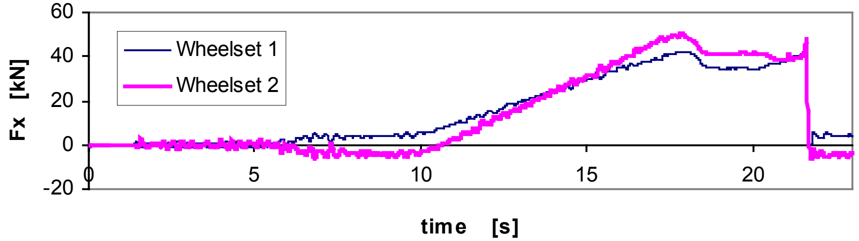
Vehicle speed: V = 70 km/h

Rail conditions: wet

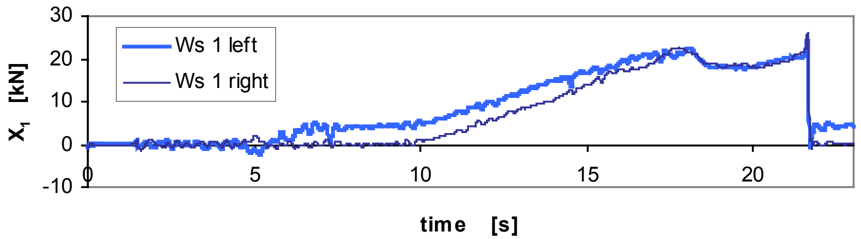
Rotor traction torque



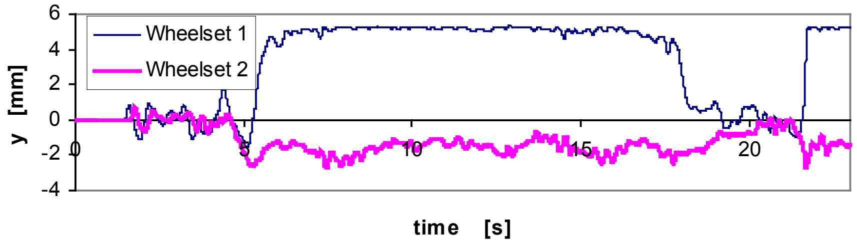
Longitudinal force in steering linkages



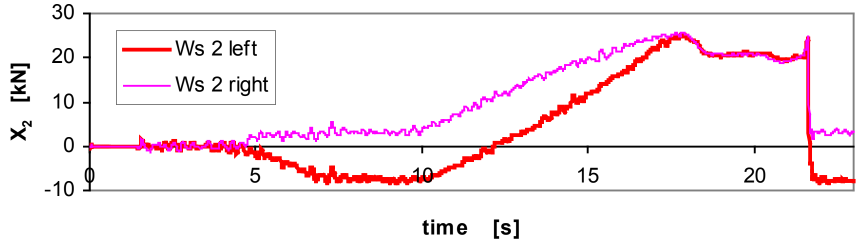
Longitudinal force of wheelset 1



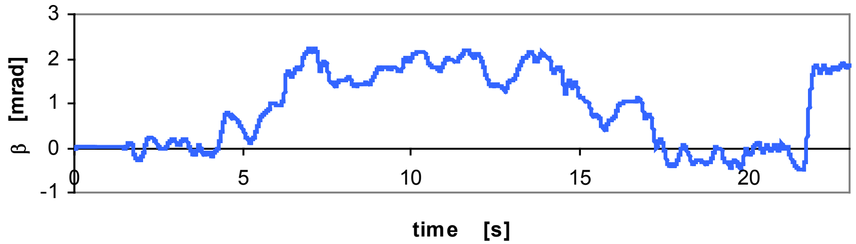
Lateral displacement of wheelset relative to track



Longitudinal force of wheelset 2

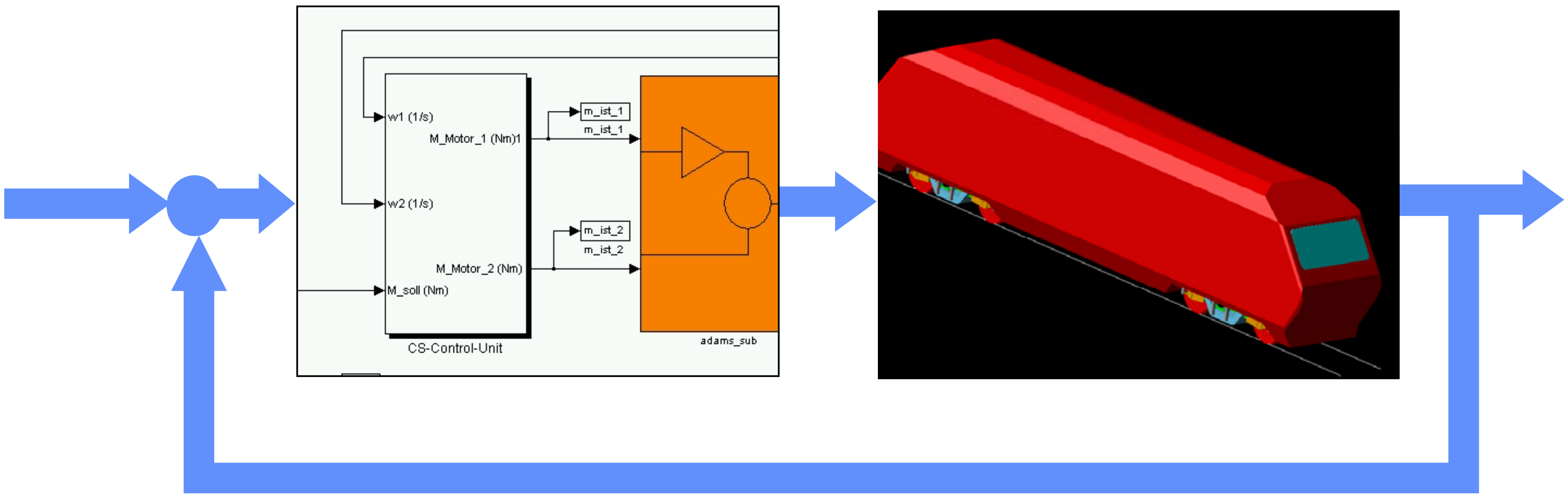


Steering angle between the wheelsets

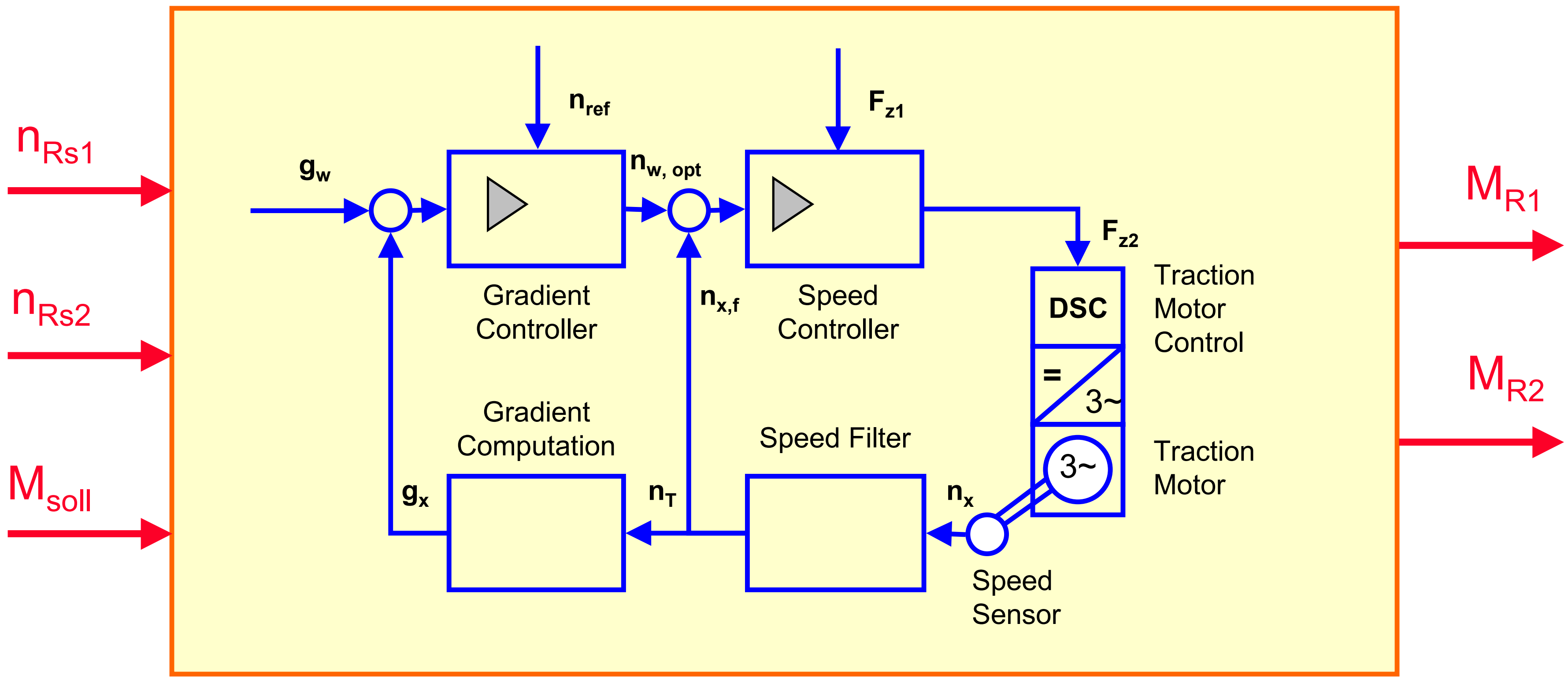


Co-Simulation of Vehicle Dynamics and Traction Control

- Adhesion Controller (MATLAB-SIMULINK)
- Mechanics (ADAMS/Rail)



Co-Simulation of Vehicle Dynamics and Traction Control



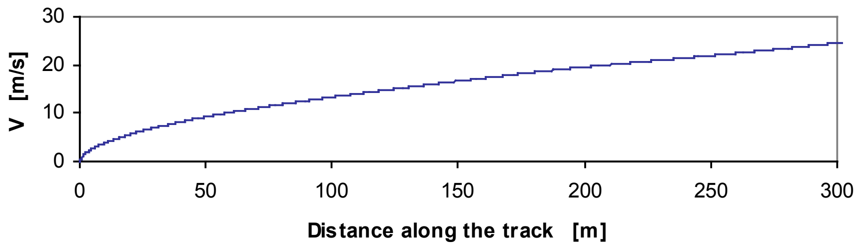
Co-Simulation Results of the Interaction of Vehicle Dynamics and Traction Control

ADtranz

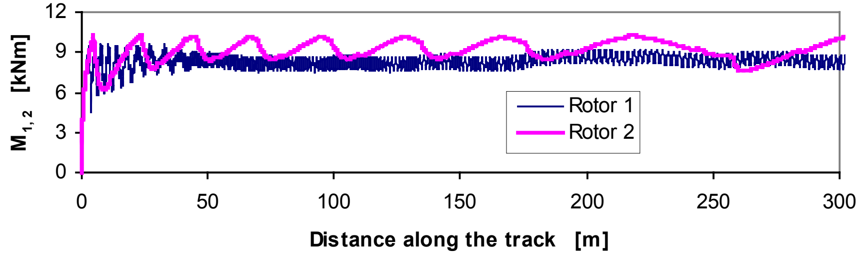
Track design: straight, curve R = 300 m, straight, curve R = 385 m

Rail conditions: wet

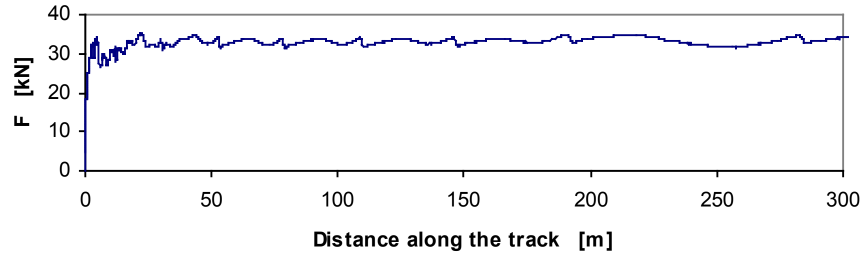
Vehicle speed



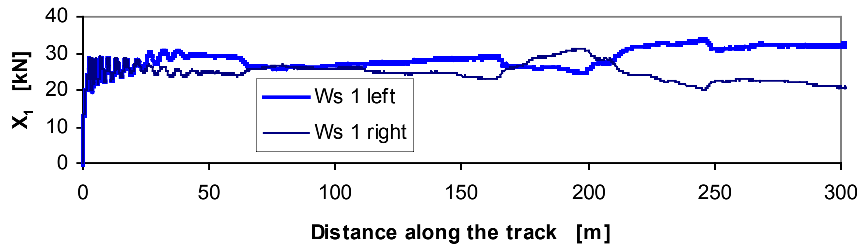
Rotor torque



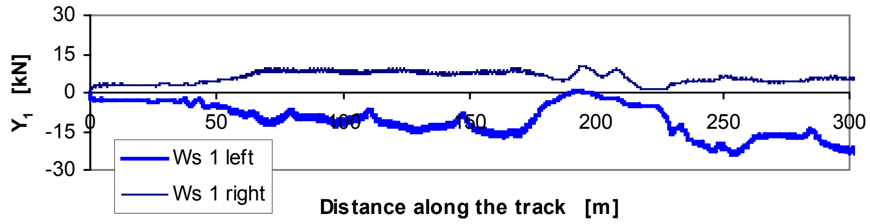
Traction rod force



Longitudinal force of wheelset 1



Lateral force of wheelset 1



Steering angle between the wheelsets

Conclusions

ADtranz

- The method of wheel-rail forces calculation developed by the author is suitable for computation of full non-linear wheel-rail forces; it takes spin into account and saves calculation time
- The presented extension of the proposed method allows a parallel simulation of vehicle and drive dynamics
- The proposed method was verified by measurements and is suitable for investigations of interaction of traction dynamics, traction control and vehicle behaviour