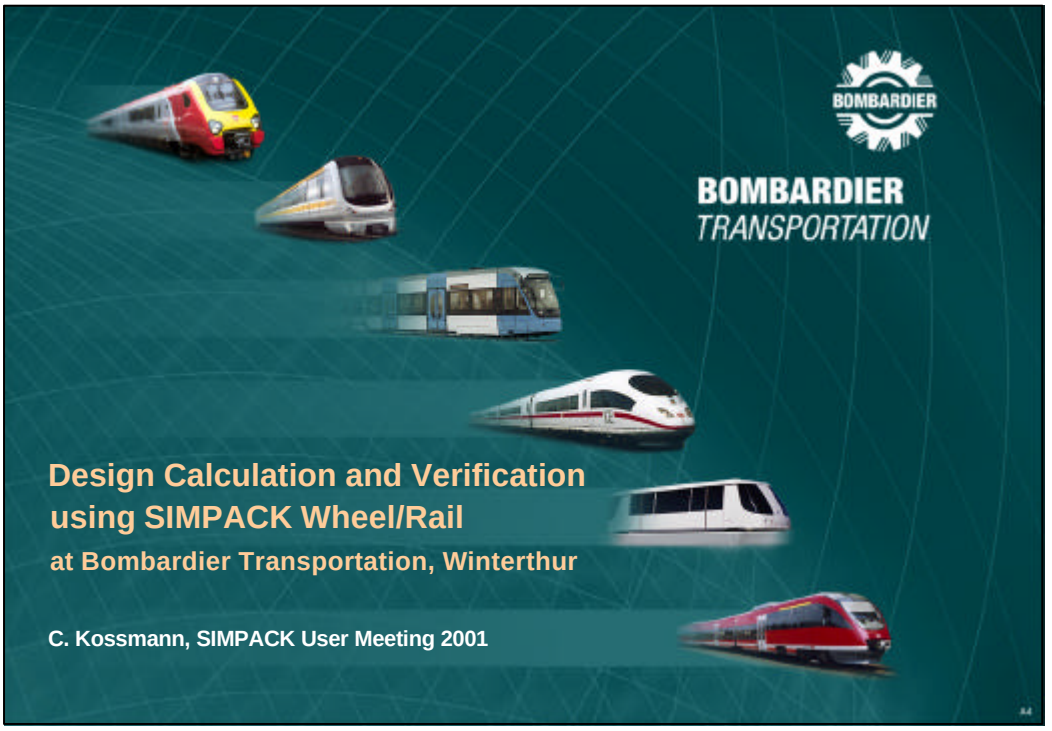


Bombardier Transportation, Site Winterthur

Business Unit Bogies

Competent for

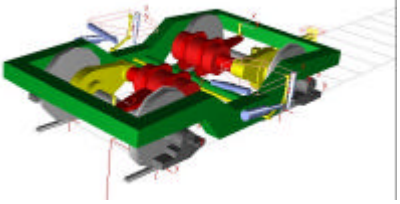
- **Single Axle Running Gears**
- **Bogies for Regional Trains**
- **Bogies for Locomotives**
- **Bogies for Intercity Trains**

Using SIMPACK for projects since April 2000

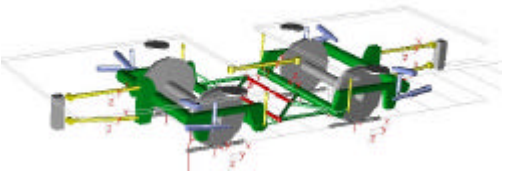
NSB EMU Class 72:

Regional Train
with Single Axle Running Gears

Motor bogie (MB)



Coupled single axle running gears (EAF)

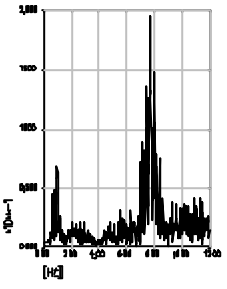


Design Calculation and Verification using SIMPACK Wheel/Rail
at Bombardier Transportation, Winterthur

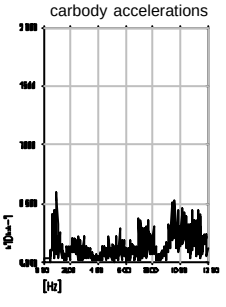
NSB EMU Class 72:

- **Running quality calculations with elastic carbody structure by INTEC GmbH in 1999**
- **By practicable changes on the carbody and on the bogies the spectra of the carbody accelerations were improved**
- **Results of the Running Quality Type Test in Norway (Summer 2001) show good agreement with simulation results**

Original spectrum of vertical carbody accelerations



Improved spectrum of vertical carbody accelerations



Light Rail Transit Car GTW 2/6
Southern New Jersey Transit

- Bogies based on LVT 646 (DB AG) and GTW Hessische Landesbahn

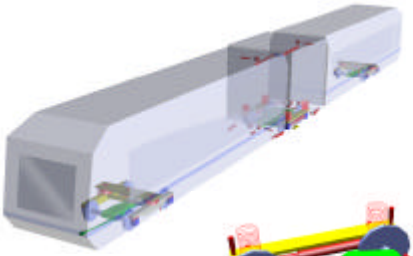
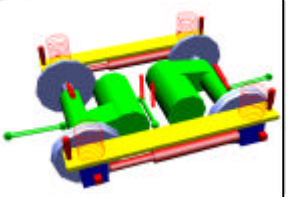
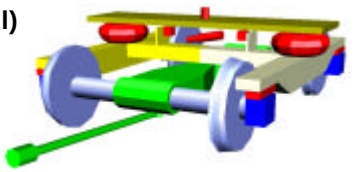


- Trailer bogie new designed to enable running through 40 m curves

Light Rail Transit Car GTW 2/6
Southern New Jersey Transit

SIMPACK Model:

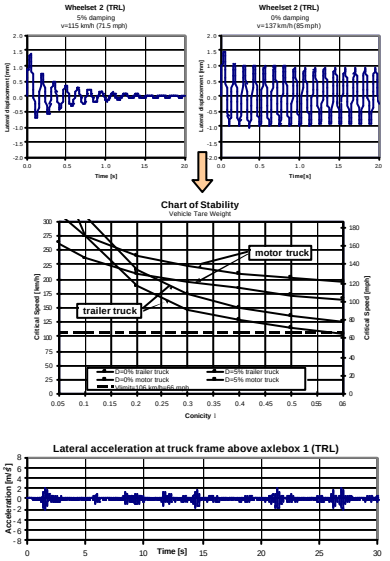
- Articulated vehicle (3 carbodies)
- Motor bogie under Power Unit
- 2 trailer bogies with smaller wheels
- Used Force Elements:
  Spring-Damper Elements (parallel, seriell)
  Friction Element

Light Rail Transit Car GTW 2/6
Southern New Jersey Transit

Stability Analysis:

- **Parameter Variation with linearized wheel/rail contact:**
  Not possible with two wheelset types
- **Stability investigation with linear wheel/rail contact in time domain with friction element**
- **Simulation with track irregularities and high conicity**
  Evaluation of lateral acceleration at the bogie frames

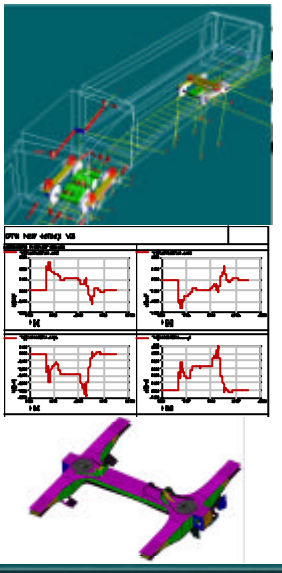


Design Calculation and Verification using SIMPACK Wheel/Rail
at Bombardier Transportation, Winterthur

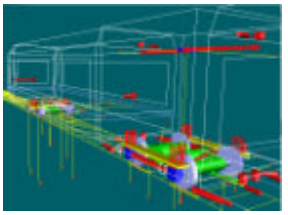
Light Rail Transit Car GTW 2/6
Southern New Jersey Transit

Calculation of forces for fatigue investigation, e.g.:

- **Simulation of curving through 40 m curve**
- **Evaluation of forces relevant for structural mechanics**
- **FEM calculation**



Light Rail Transit Car GTW 2/6
Southern New Jersey Transit

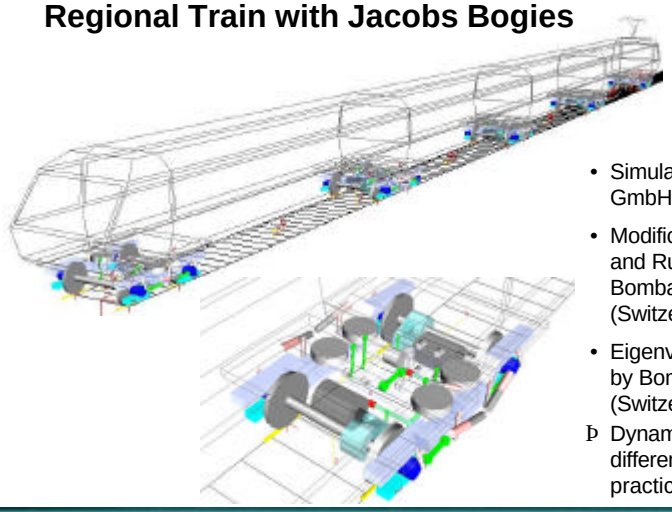


Sidewind Analysis

Evidence that Q > 0 and Y/Q below the limit value for:

- **the narrowest curve**
- **Running with maximum speed on straight track with irregularities**
- **Running slowly through a curve with maximum superelevation**

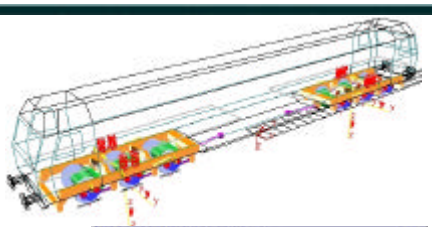
CP 2000:
Regional Train with Jacobs Bogies



- Simulation model made by INTEC GmbH in 2000
- Modification of the simulation model and Running Quality Calculations by Bombardier Transportation (Switzerland) in Pratteln
- Eigenvalue and Stability calculations by Bombardier Transportation (Switzerland) in Winterthur

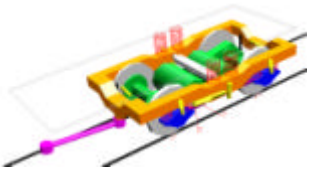
Þ Dynamic simulation project at different sites with SIMPACK practicable

SIMPACK “Lok-Pool”



Complete parameterization of Locomotives models:

- BR 145
- BR 146
- BR 101
- Blue Tiger
- BR 128 (12X)



Substructures: Bogies and Carbodies

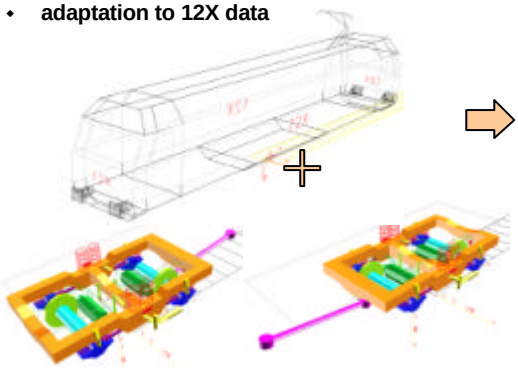
Parameters: mass properties, marker position, stiffness and damping values

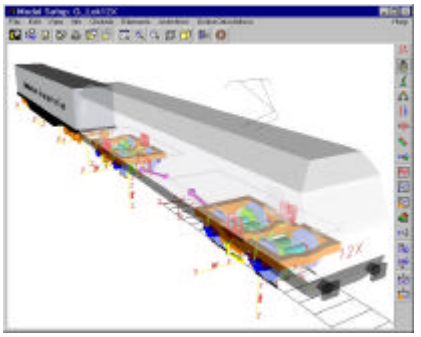
BR 128 (Lok 12X)

Co-Simulation with MATLAB SIMULINK

SIMPACK model

- originated from completely parameterised BR 146 model
- substructures: bogies and carbody
- adaptation to 12X data

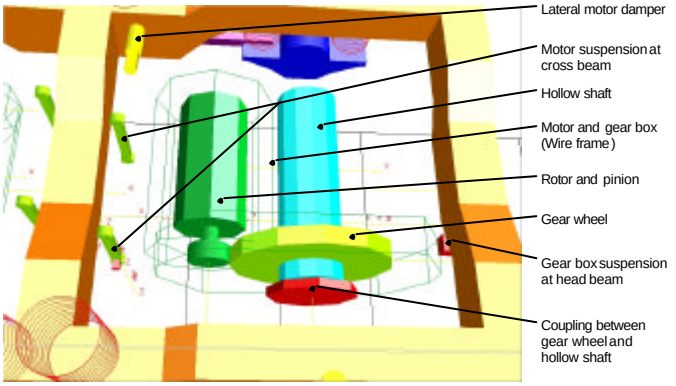




BR 128 (Lok 12X) Co-Simulation with MATLAB SIMULINK

Detailed drive model

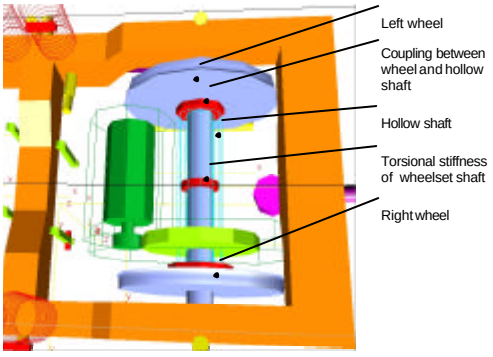
- Hollow shaft
- Gear wheel
- Pinion and Rotor
- Motor and gearbox



Design Calculation and Verification using SIMPACK Wheel/Rail
at Bombardier Transportation, Winterthur

BR 128 (Lok 12X) Co-Simulation with MATLAB SIMULINK

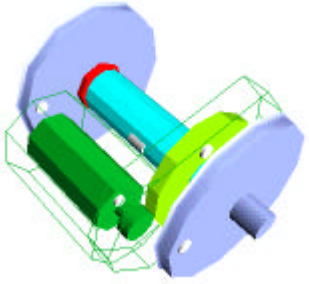
Wheelset with torsional-elastic axle



Eigenmodes of drive

„Rattern“ (21.7 Hz)

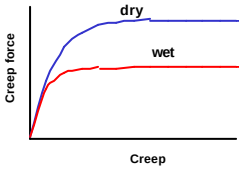
„Rollieren“ (49.2 Hz)



BR 128 (Lok 12X) Co-Simulation with MATLAB SIMULINK

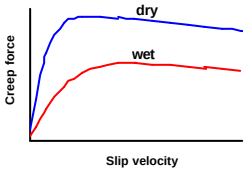
Necessity of extension of wheel/rail contact model

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

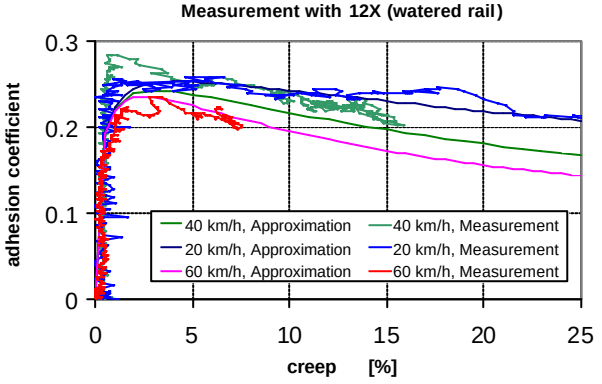
User routine for the friction law of wheel/rail contact force

BR 128 (Lok 12X) Co-Simulation with MATLAB SIMULINK

Approximation of measured creep force function

Evaluation of

- maximum friction coefficient μ_0
- ratio of μ_∞ (limit friction coefficient at infinity slip velocity) to μ_0
- coefficient of exponential friction decrease
- Kalker factor in area of adhesion
- Kalker faktor in area of slip



BR 128 (Lok 12X) Co-Simulation with MATLAB SIMULINK

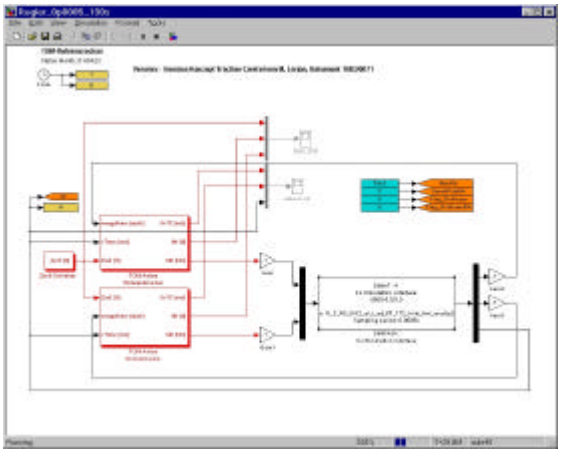
Implementation of mechanical model in SIMULINK control

SIMPACK output:

- Rotating speed of rotor 3
- Rotating speed of rotor 4
- Velocity

SIMPACK input:

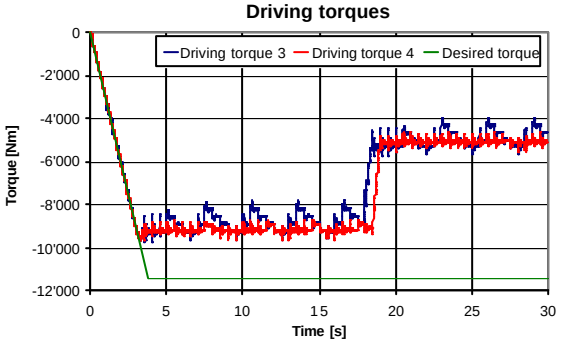
- Driving torque of rotor 3
- Driving torque of rotor 4

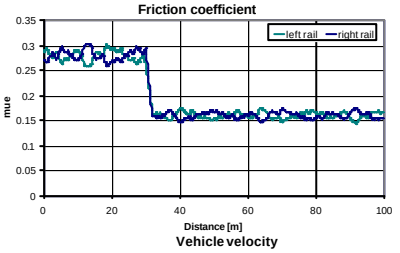


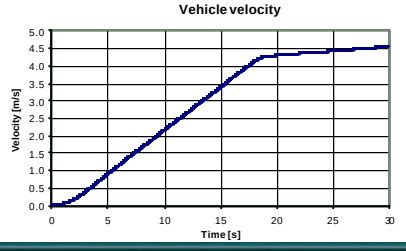
Design Calculation and Verification using SIMPACK Wheel/Rail
at Bombardier Transportation, Winterthur

BR 128 (Lok 12X) Co-Simulation with MATLAB SIMULINK

Simulation results: Starting up on straight track with variable friction coefficient

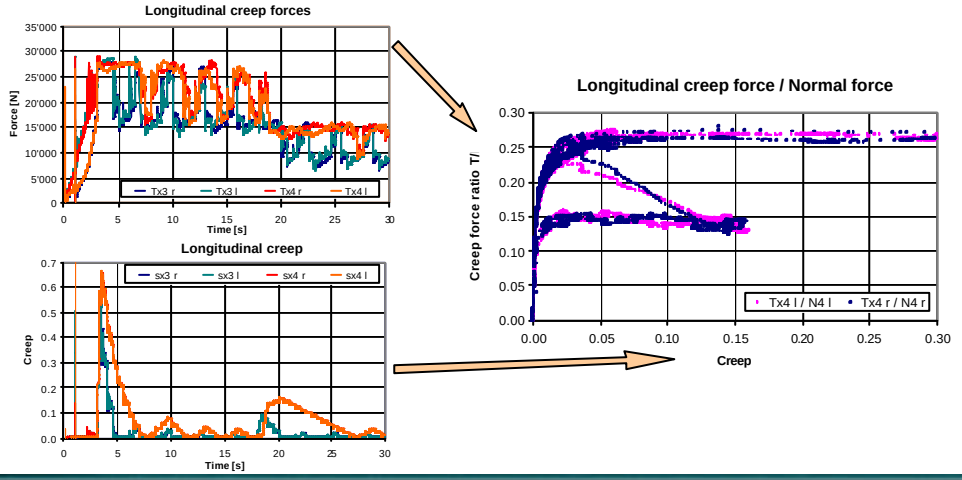






BR 128 (Lok 12X) Co-Simulation with MATLAB SIMULINK

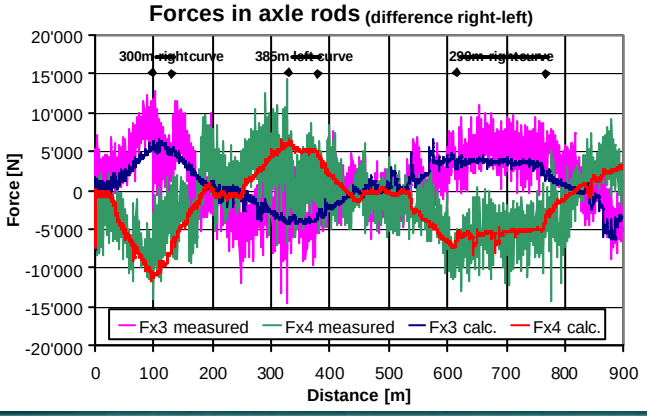
Simulation results: Starting up on straight track with variable friction coefficient

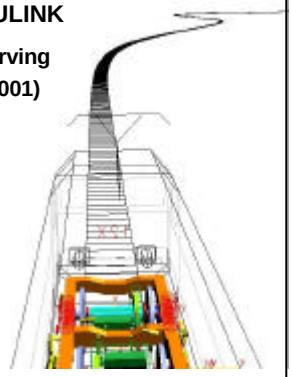


Design Calculation and Verification using SIMPACK Wheel/Rail
at Bombardier Transportation, Winterthur

BR 128 (Lok 12X) Co-Simulation with MATLAB SIMULINK

Simulation results: Starting up on straight track followed by curving
Comparison with measurements with 12X (Kanderviadukt, Aug. 2001)

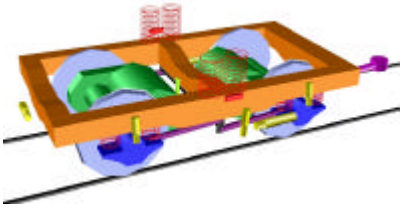




Present and further activities

4 System Locomotive:
New bogies based on BR 145/146:

- Unsuspended Drive
- Suspended Drive
- Each variation with or without coupling system for radial steering



Co-simulation:

- Getting more experience using SIMAT
- Building up additional know-how
- Applying co-simulation in further fields of bogie engineering