Simulation of the tilting train VT611/612

Dr. Bernhard Morys, Dr. Thomas Rosemeier, April 28th, 1999

ADtranz

we speak railways

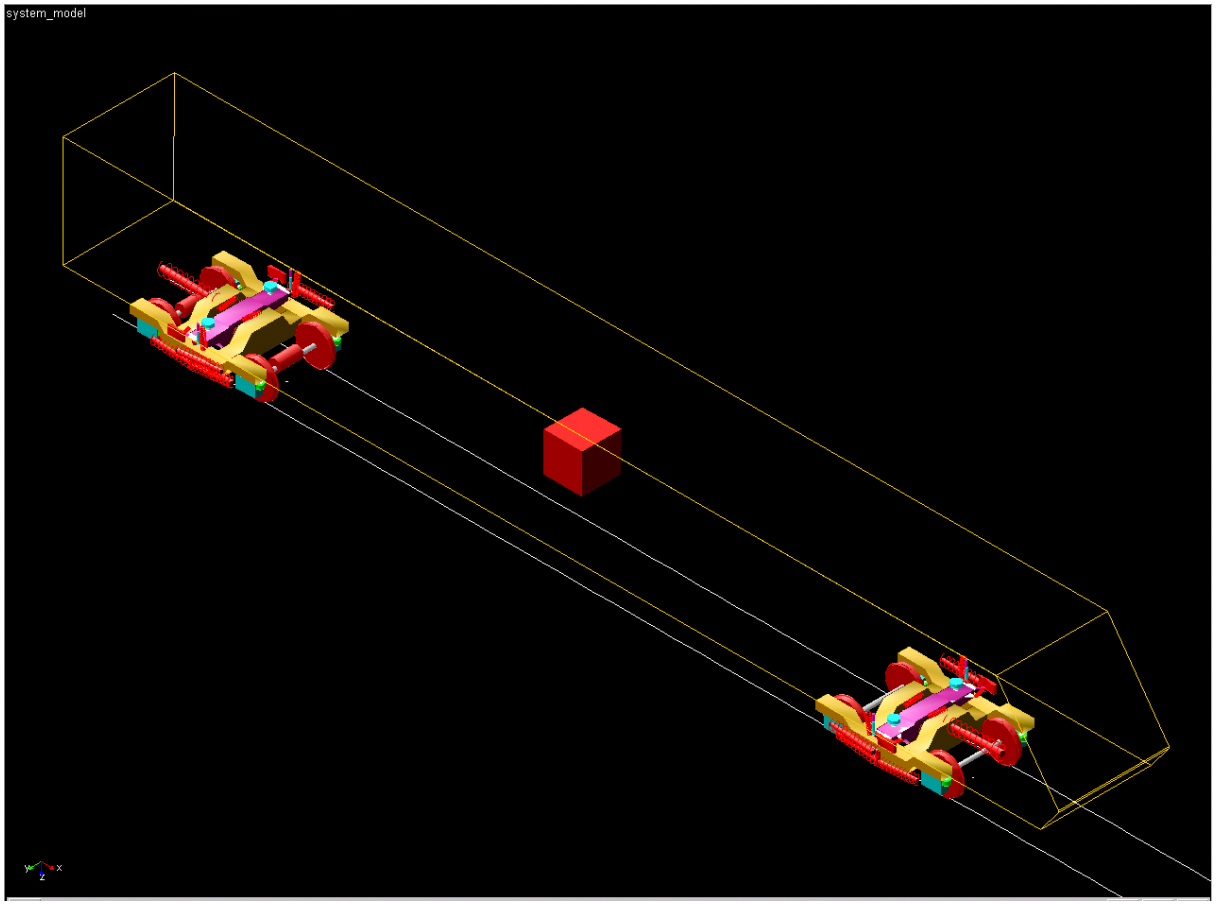
Contents

- Vehicle model:
  - Tilting system
  - Air spring
  - Lateral bumpstop
- Analysis scenarios:
  - Air spring defects
  - Wedge test
- Future model improvements

Overview vehicle model

ADtranz

we speak railways

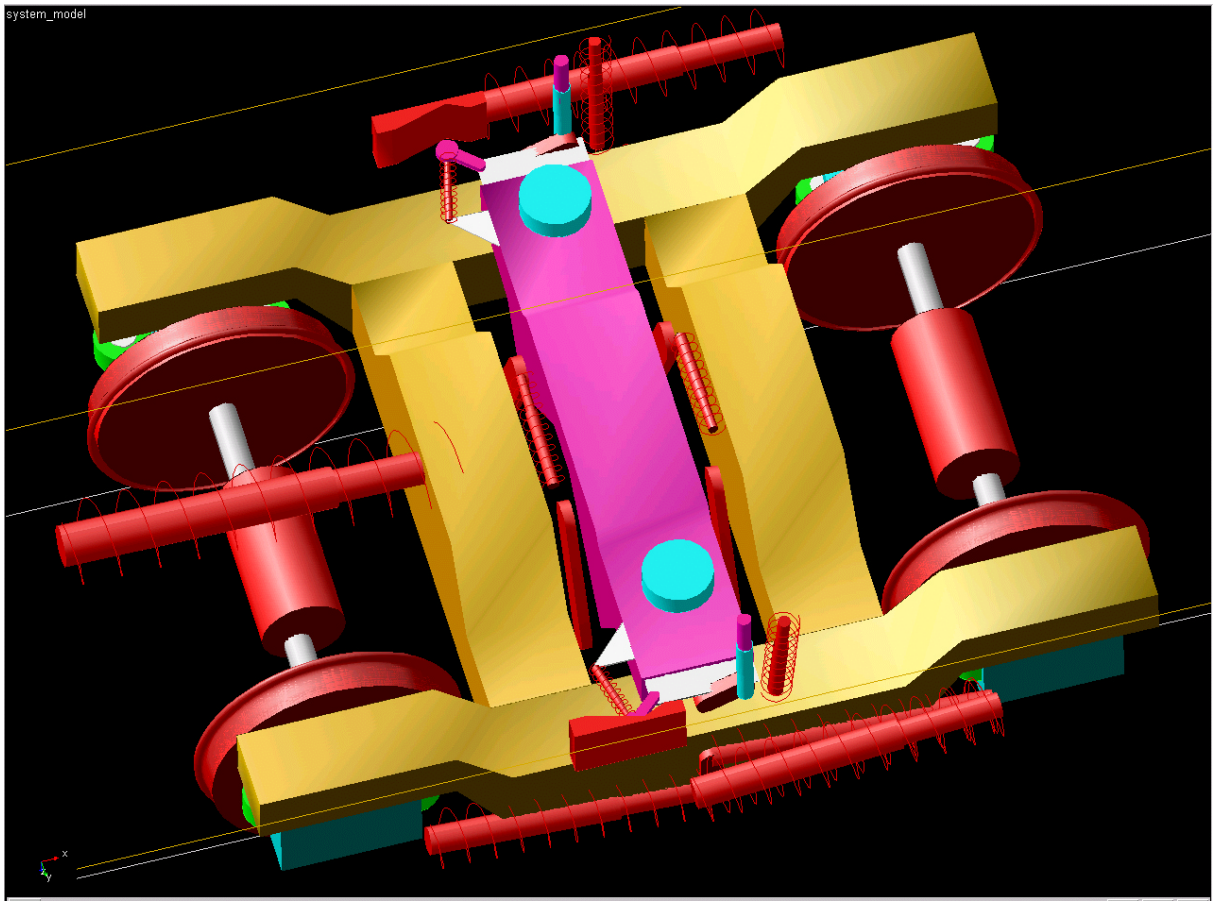


- Active/passive tilting system
- Physical air spring model
- Height control at each air spring
- Traction
- Car body with torsional elasticity
- 61 DOF

Bogie (1)

ADtranz

we speak railways

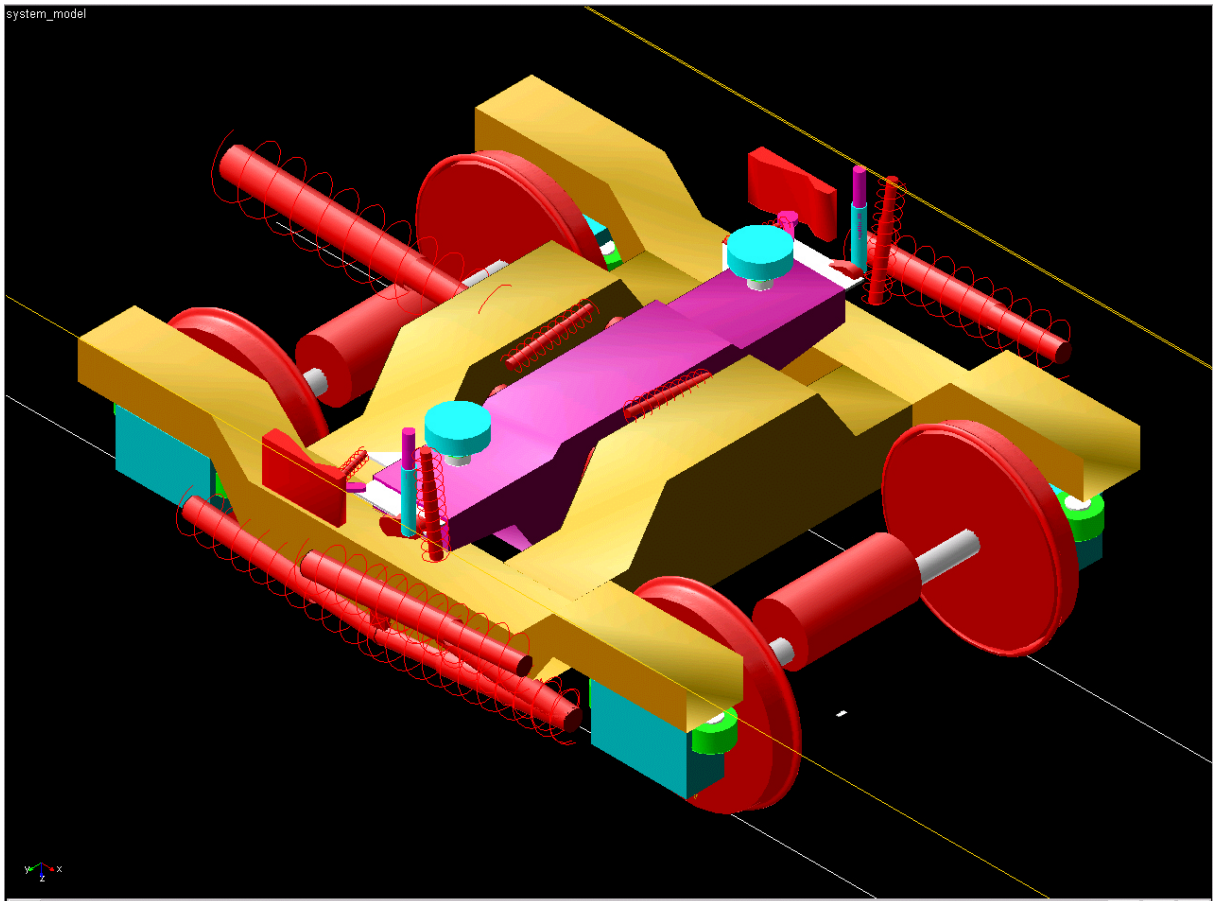


- Tilting system: bearing of bolster beam, control
- Air spring, torsion bar
- Lateral bumpstop
- Draw rod

Bogie (2)

ADtranz

we speak railways



- Primary suspension
- Wheelset linkage
- Traction
- Wheel-rail contact:
  - Testrig
  - Level III

Air spring model (1): Physical description

ADtranz
we speak railways

- Air spring model based on gas equation:

$$\frac{p \cdot V}{T} = R_{Air} \cdot m_{Air}$$

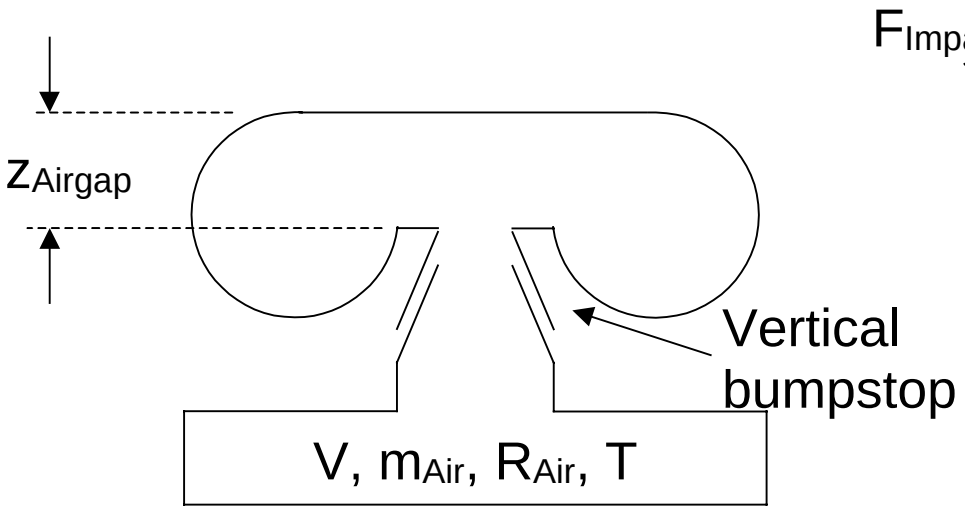
$$V = V_0 + \tilde{A} \cdot z_{Airgap}$$

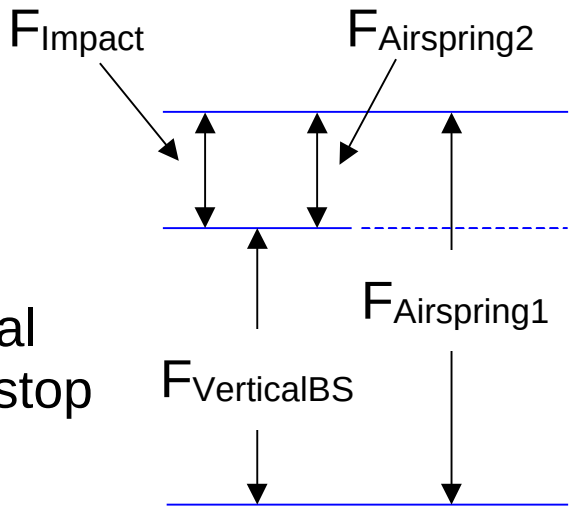
$$\frac{F_{AirspringX}}{A_X} = [p - p_{atm}]$$

$$F_{AirspringX}(z_{Airgap}, m_{Air}) = A_X \cdot \left[\frac{T \cdot R_{Air} \cdot m_{Airt}}{V_0 + \tilde{A} \cdot z_{Airgap}} - p_{atm} \right]$$

Air spring model (2):
Module air spring/vertical bumpstop

ADtranz
we speak railways





Parts:

Car body

Upper end of vertical bump-stop

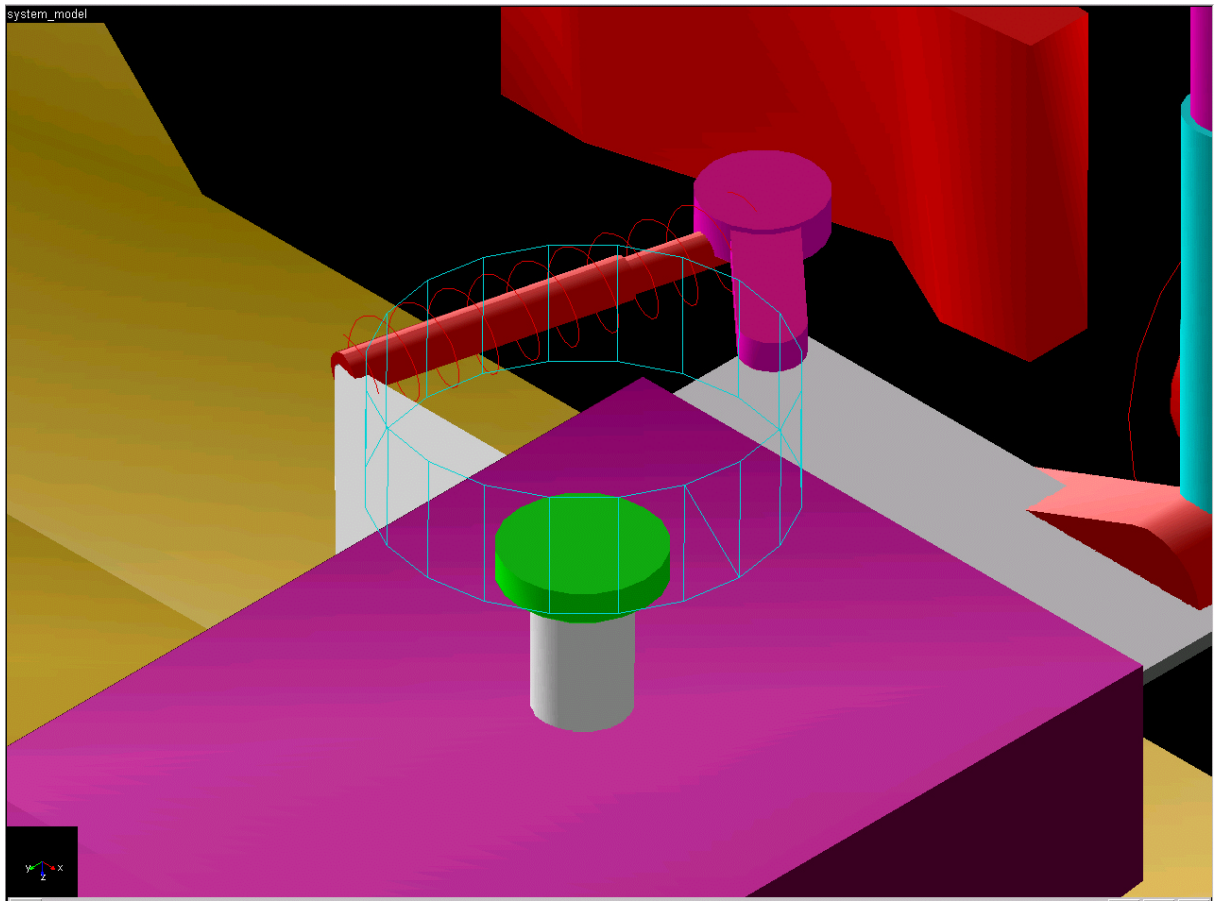
bulster beam

- Impact at zero air gap ($z_{Airgap} = 0$)
- Non-linear measured characteristics of vertical bumpstop
- Linear air spring characteristic in longitudinal and lateral direction

Air spring model (3): Implementation in ADAMS/Rail

ADtranz

we speak railways



Air spring model (4): Change of air mass

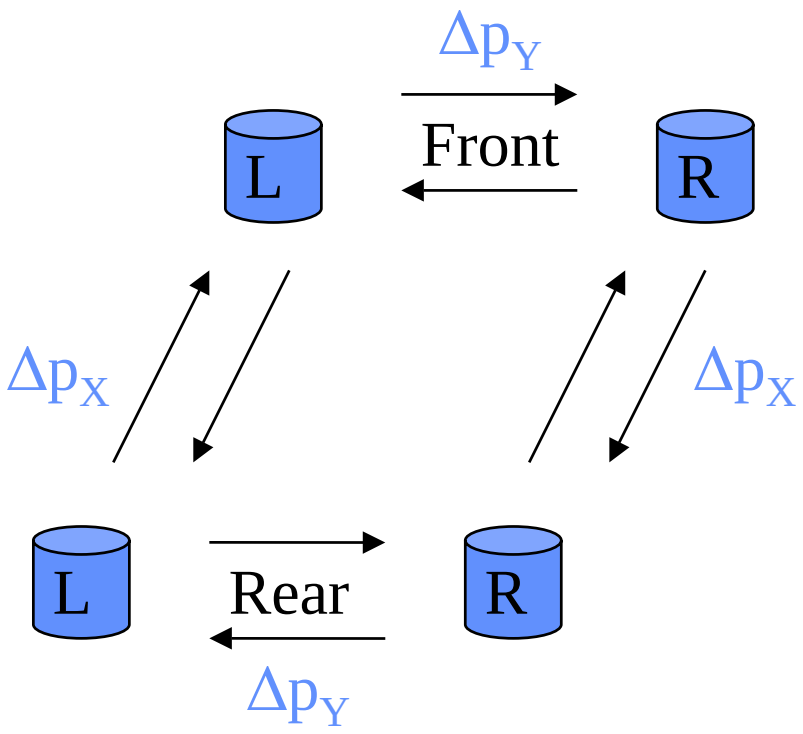
ADtranz
we speak railways

$$m_{Air} = \int \left[f_{Heightcontrol} + f_{Massequ} + f_{Hole} \right] \cdot dt + m_{Air\,0}$$

- Height control $f_{Heightcontrol}(\alpha)$ of the air gap of each spring (Real valve characteristics)
- Mass flow $f_{Massequ}(\Delta p)$ between air spring bellows for $\Delta p > \Delta p_0$
- Alternatively pressure equalisation between two bellows
- Holes/leaking bellows as error scenario ($f_{Hole} < 0$)
- Air masses are implemented as differential equations (DIFF-statements)

Air spring model (5):
Mass flow between bellows for $\Delta p > \Delta p_0$

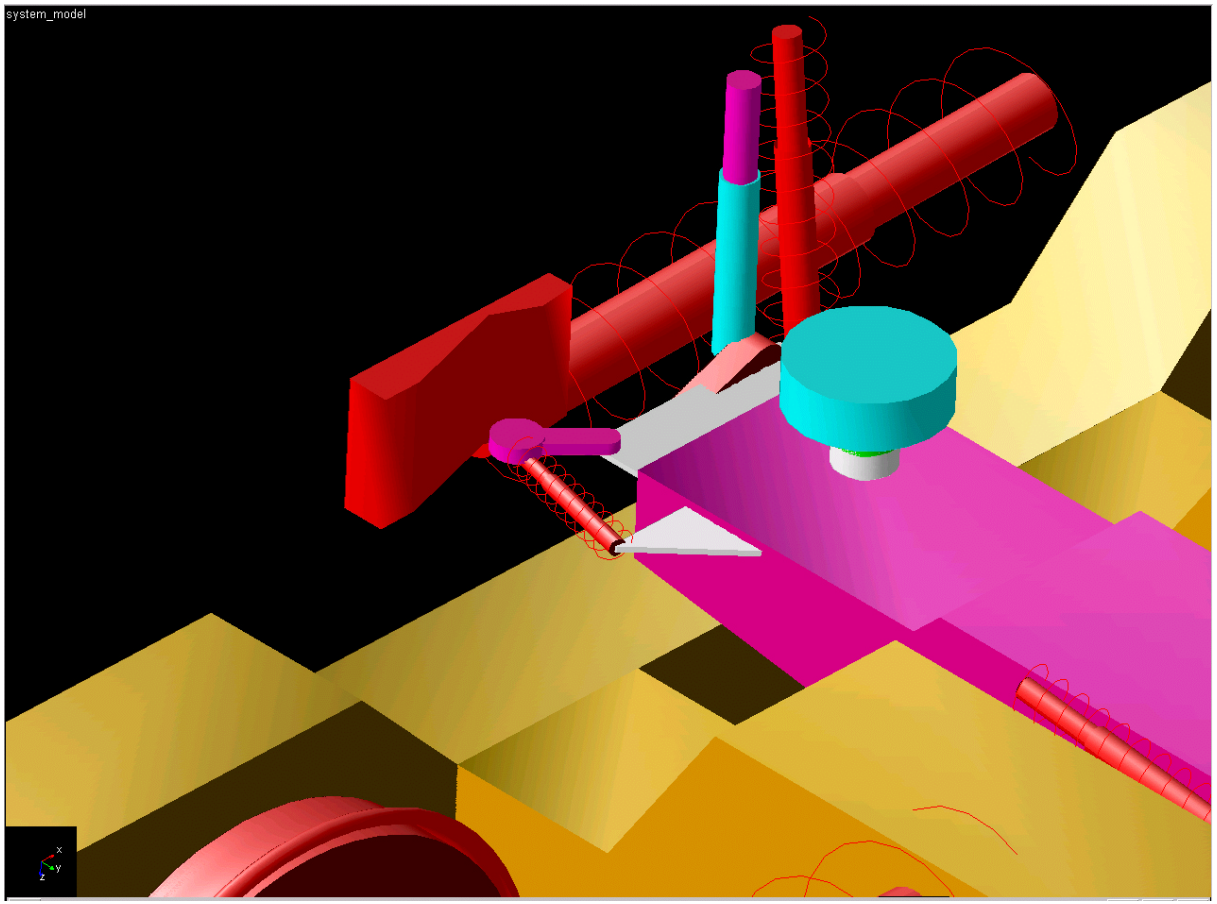
ADtranz
we speak railways



Lateral bumpstop car body bogie (1)

ADtranz

we speak railways

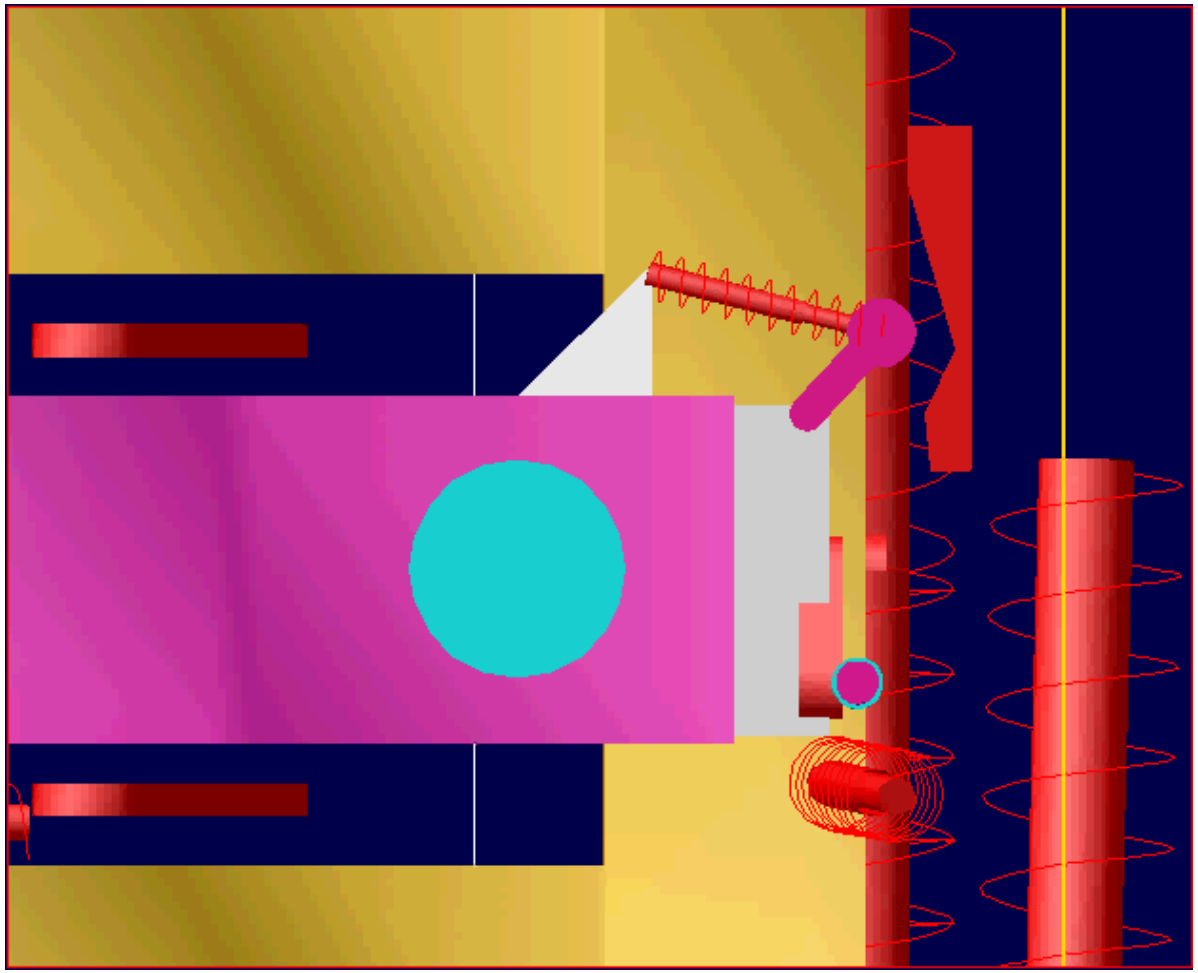


- Bearing of guide roller
- Form and position of contour plate
- Contact force at impact

Lateral bumpstop car body bogie (2): Lateral force on the car body

ADtranz

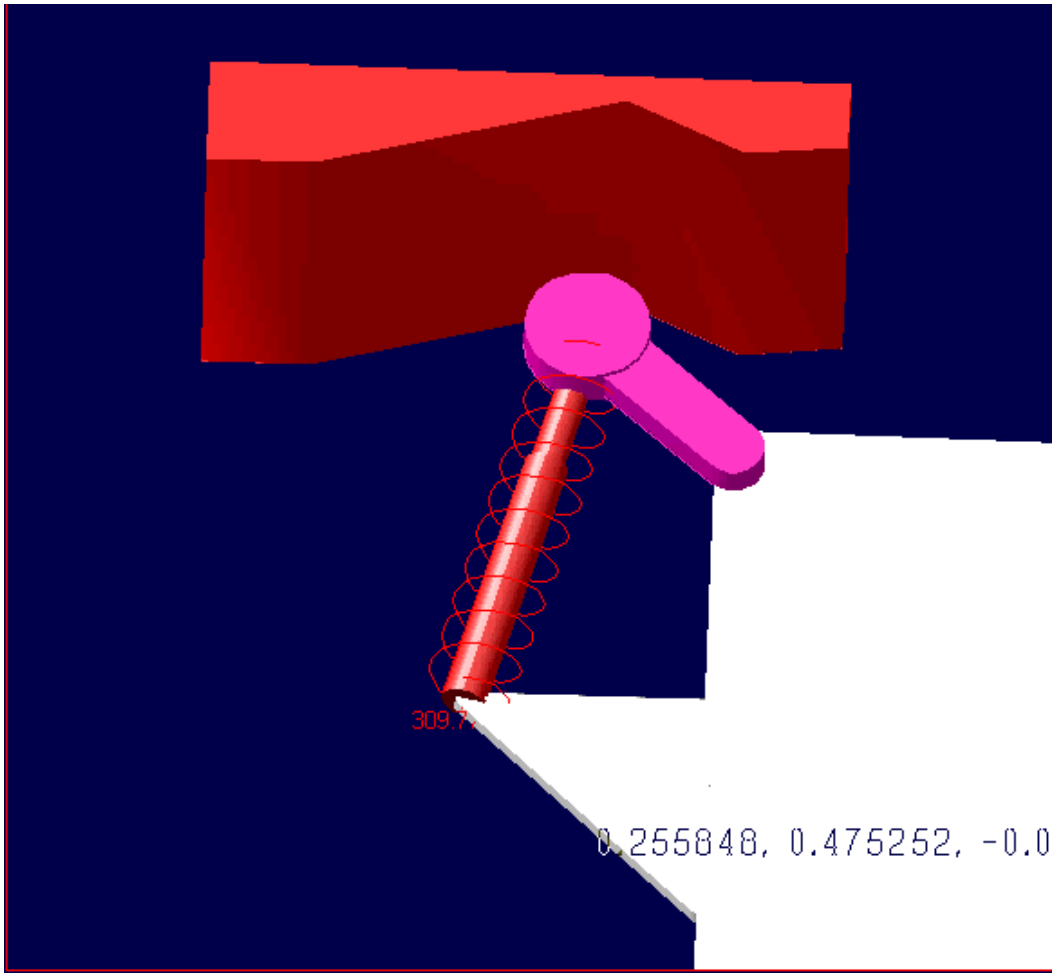
we speak railways



Lateral bumpstop car body bogie (3): Lateral impact

ADtranz

we speak railways

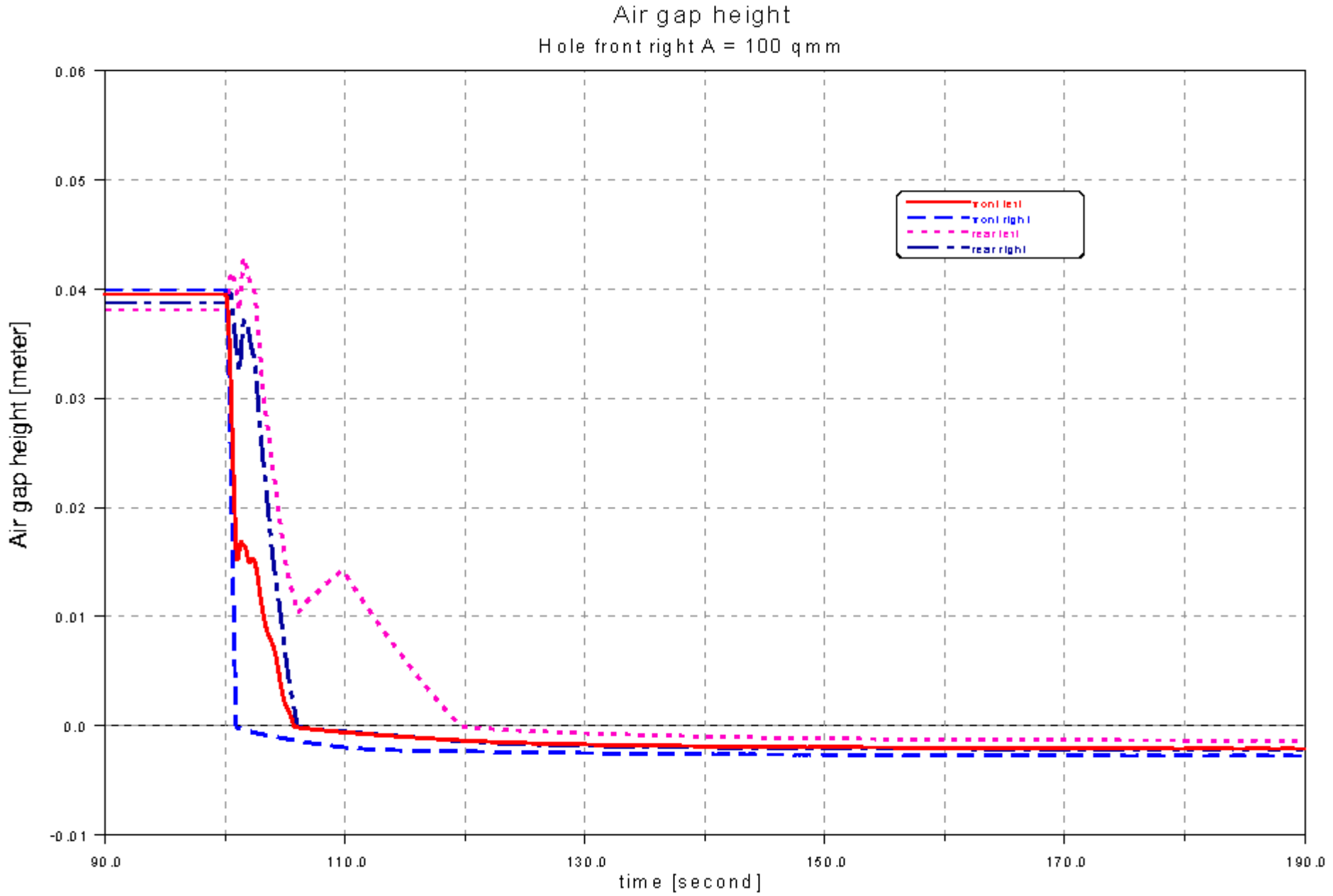


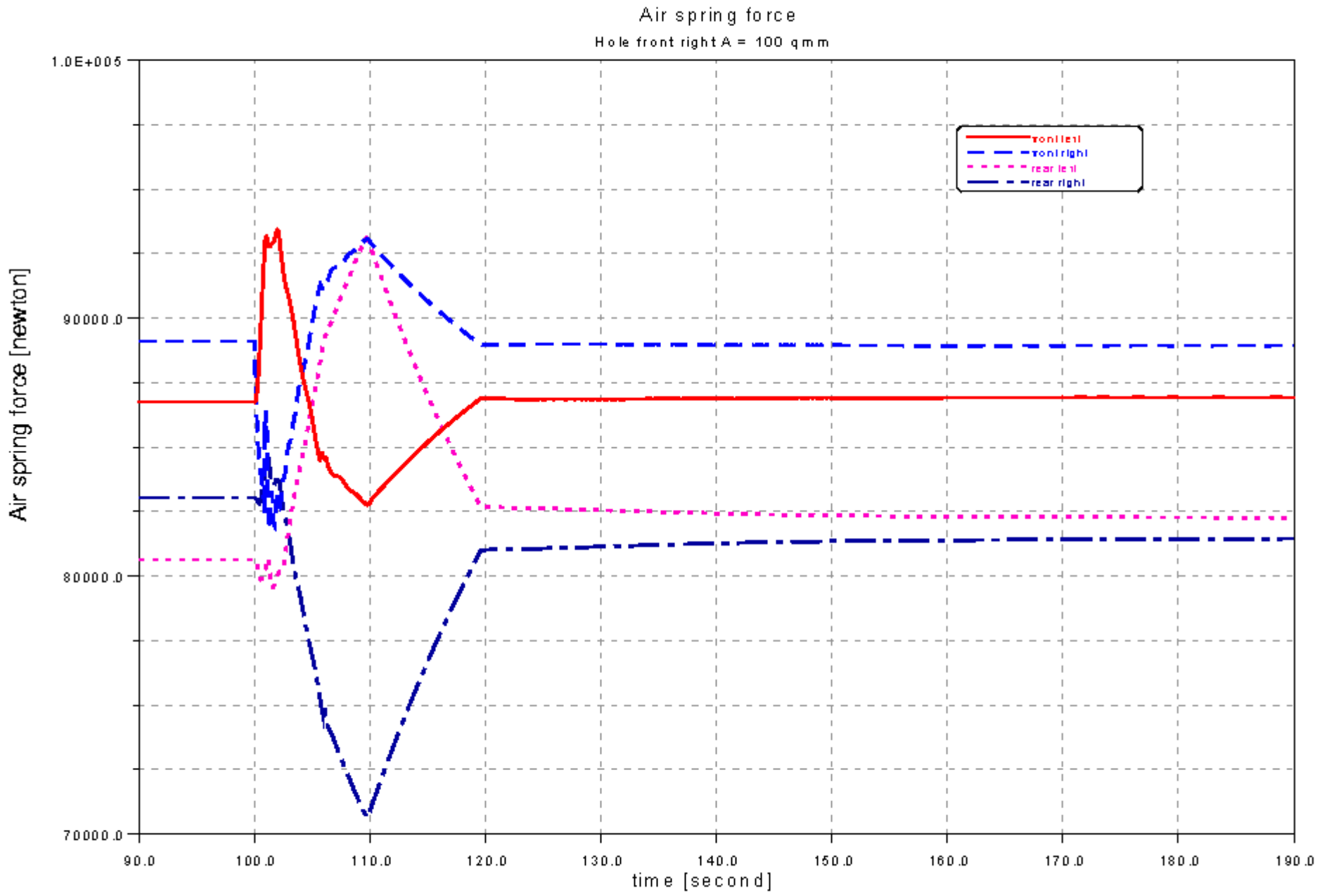
Simulation scenarios

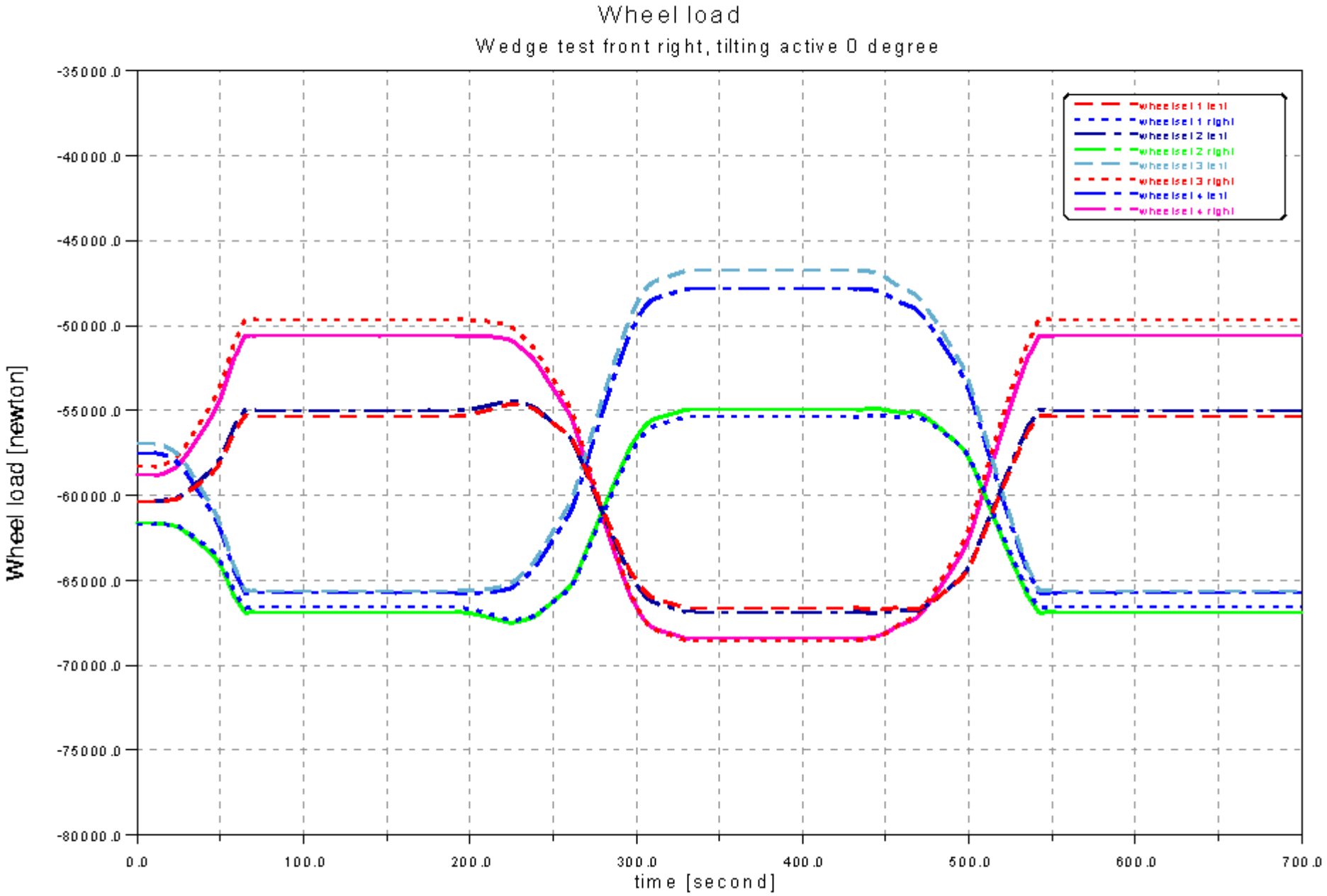
ADtranz

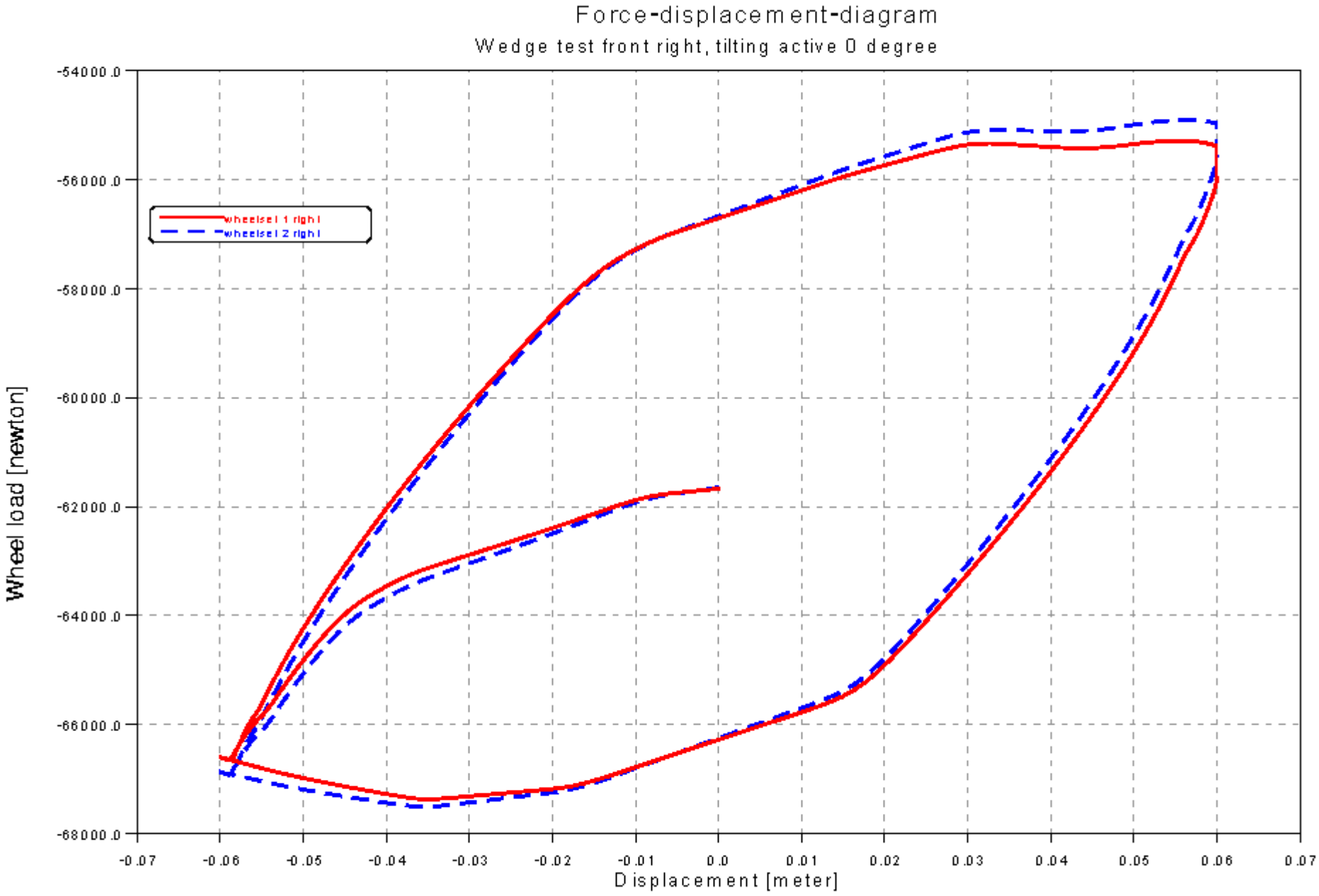
we speak railways

- Adjustment of the air spring height control
- Error scenarios:
  - Defects of the air spring height control
  - Hole/leak in air spring bellows
- Wedge test
- Kinematics of the bogie
- Vehicle examination procedure
- etc.


Air gap height
Hole front right A = 100 qmm
front left
front right
rear left
rear right
Air gap height [meter]
0.06
0.05
0.04
0.03
0.02
0.01
0.0
-0.01
90.0
110.0
130.0
150.0
170.0
190.0
time [second]


Air spring force
Hole front right A = 100 qmm
1.0E+005
90000.0
80000.0
70000.0
Air spring force [newton]
90.0
100.0
110.0
120.0
130.0
140.0
150.0
160.0
170.0
180.0
190.0
time [second]
front left
front right
rear left
rear right


Wheel load
Wedge test front right, tilting active 0 degree
Wheel load [newton]
time [second]
-35000.0
-40000.0
-45000.0
-50000.0
-55000.0
-60000.0
-65000.0
-70000.0
-75000.0
-80000.0
0.0
100.0
200.0
300.0
400.0
500.0
600.0
700.0
wheelsel 1 left
wheelsel 1 right
wheelsel 2 left
wheelsel 2 right
wheelsel 3 left
wheelsel 3 right
wheelsel 4 left
wheelsel 4 right


Force-displacement-diagram
Wedge test front right, tilting active 0 degree
wheelsel 1 right
wheelsel 2 right
-54000.0
-56000.0
-58000.0
-60000.0
-62000.0
-64000.0
-66000.0
-68000.0
Wheel load [newton]
-0.07
-0.06
-0.05
-0.04
-0.03
-0.02
-0.01
0.0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
Displacement [meter]

Future model improvements

ADtranz

we speak railways

- Test of “classical” vehicle dynamics calculation:
  - Vehicle model
  - Simulation environment
- Dynamical air spring model (stiffening at higher frequencies)
- Powertrain

Summary

ADtranz

we speak railways

- Development of a VT611/612 vehicle model with *detailed* description of:
  - Tilting system
  - Secondary suspension
  - Air spring model (based on the gas equation)
  - Bogie kinematics
- Analysis of:
  - Adjustment and error scenarios of air spring system
  - Bogie kinematics
  - Vehicle examination procedure
- Future improvements/analyses:
  - Implementation of the complete powertrain
  - “Classical” vehicle dynamics