VI-Rail v16

…much more than railway dynamics…

Gabriele Ferrarotti – Rail Industry Manager - VI-grade

VI-Rail
History

- Based on ADAMS (general-purpose 3D fully non linear kinematics) multibody software
- Developed and maintained by VI-grade
- VI-grade spun-off MSC Software in 2005
- VI-Rail originated from ADAMS/Rail in the same year
- Lots of development efforts since then

VI-Rail

Much more than railway dynamics…

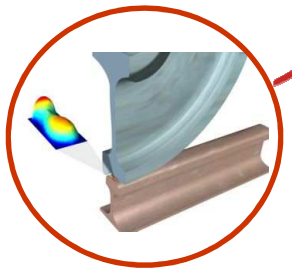
- Represents a complete solution for railway dynamics analysis, allowing to seamlessly go from component-level to system-level
- Features a very flexible, force-only wheel/rail contact model (ArgeCare – Walter Kik)
- Is constantly enhanced since 1995 thanks to the contribution of 3rd party railway specialists and research centers
- Is highly interactive and totally customizable

Railway Solutions

Vehicle dynamics & detailed simulations

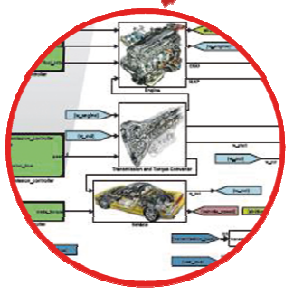
ADAMS Technology

Vehicle Dynamics, Stability, Comfort, Safety



3rd party expertise

DOE & Optimization

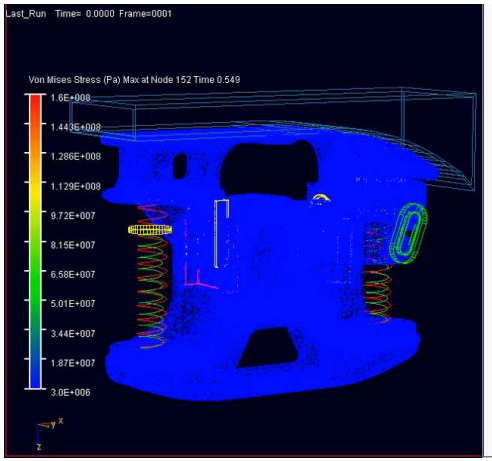


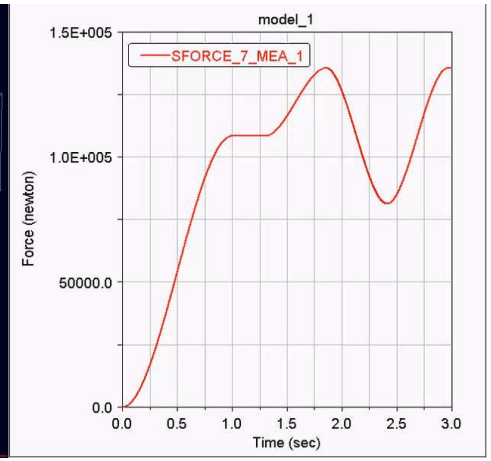
Software-in-the-loop

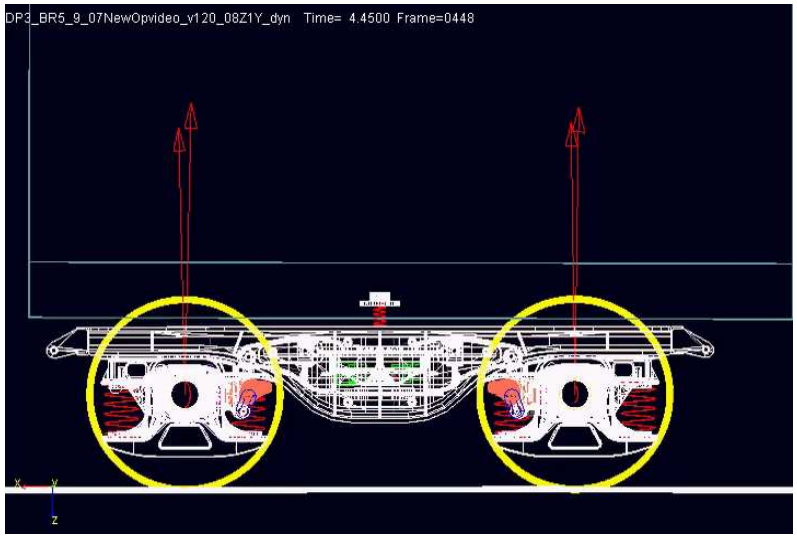
Advanced Applications (traction, braking, switch crossing, wear…)

VI-Rail

From component to system







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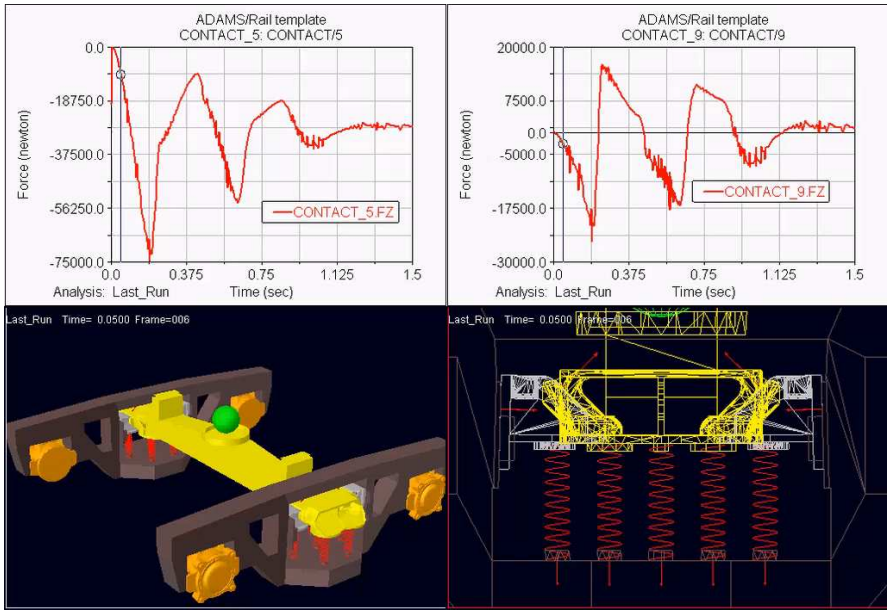
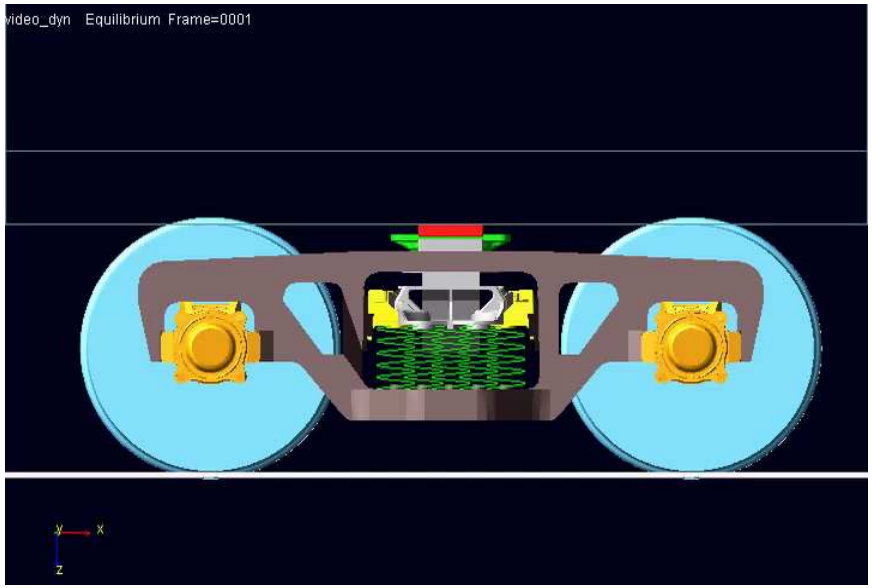
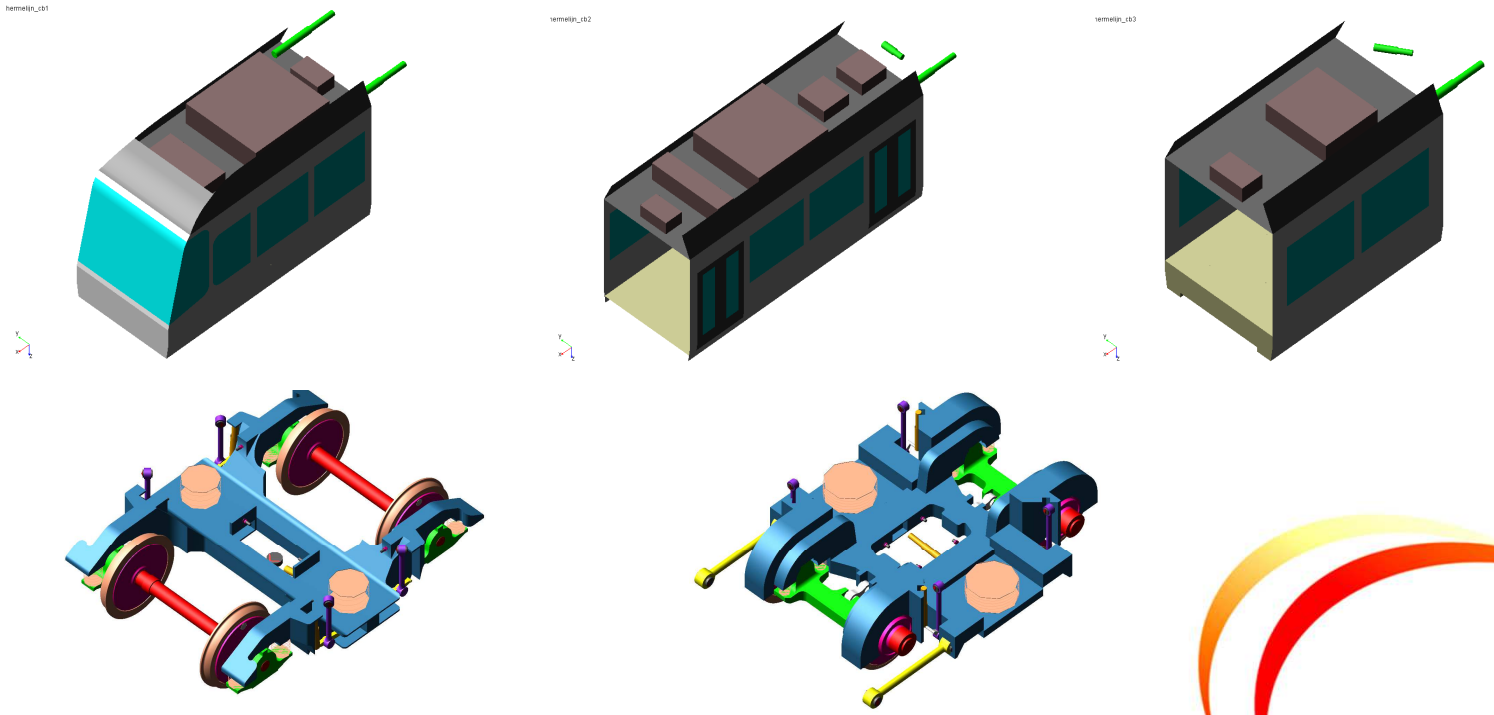
From component to system





VI-Rail
Interactive Modeling Process

- Great flexibility thanks to template structure
- Example: SIEMENS Hermelijn Streetcar



VI-GRADE

VI-Rail
Interactive Modeling Process

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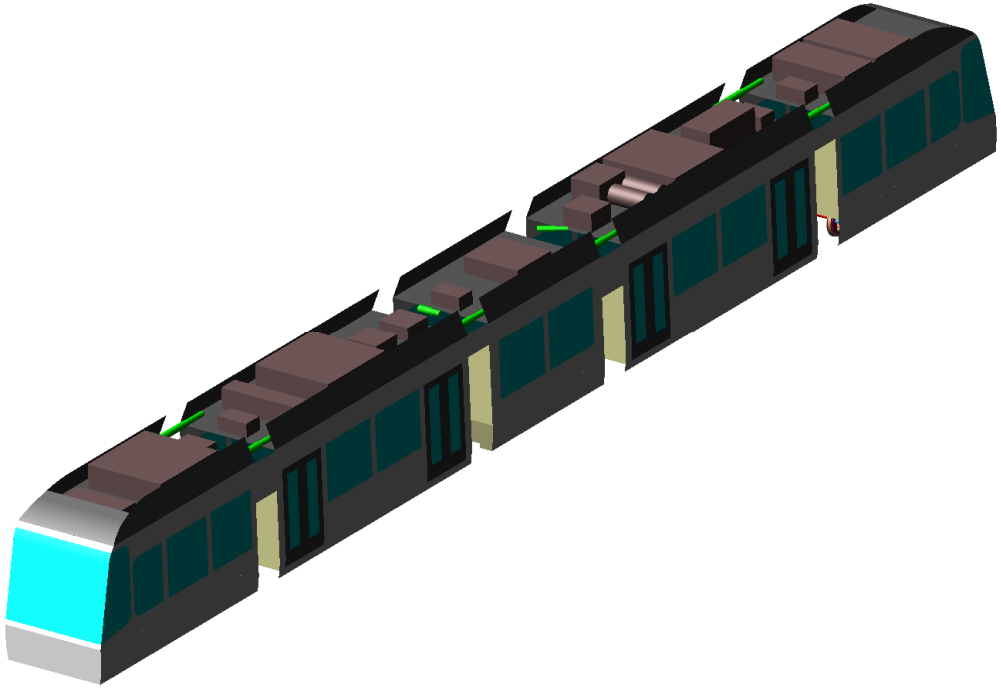
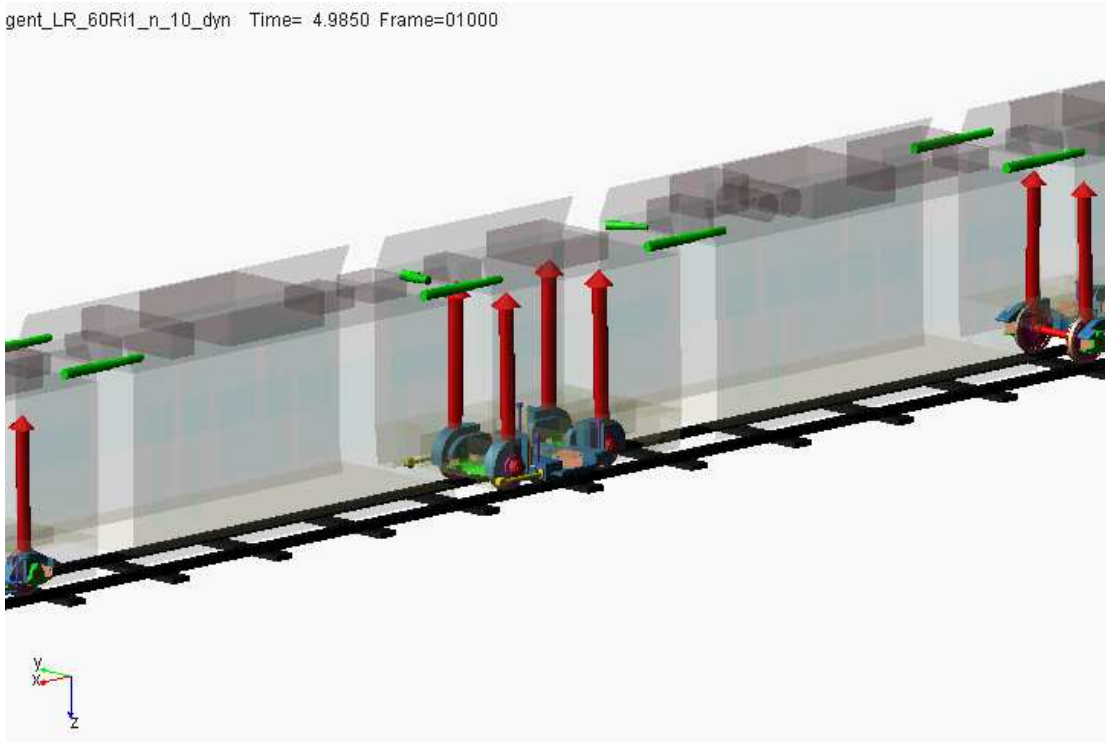


VI-GRADE

VI-Rail
Interactive Modeling Process

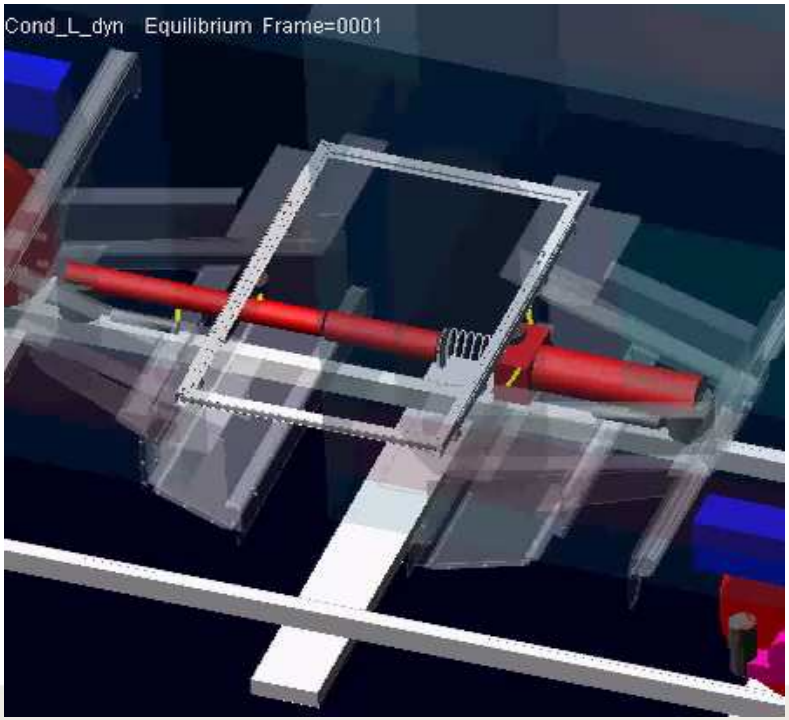
- Great flexibility thanks to template structure
- Example: SIEMENS Hermelijn Streetcar



VI-Rail

Interactive Modeling Process

- Great flexibility thanks to template structure
- Example: Interference studies in connection between subway wagons



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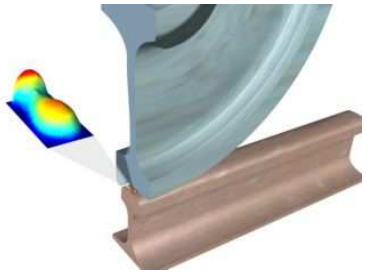
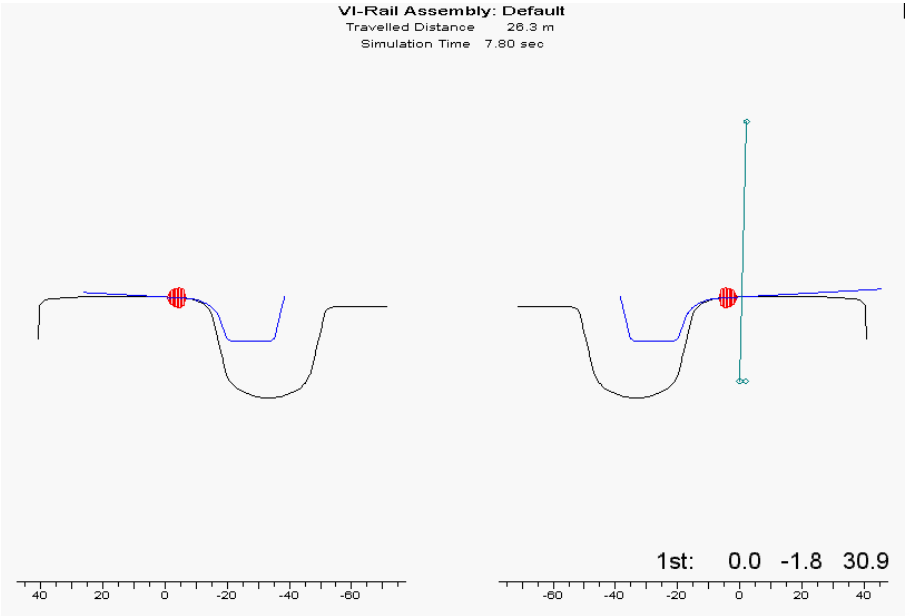
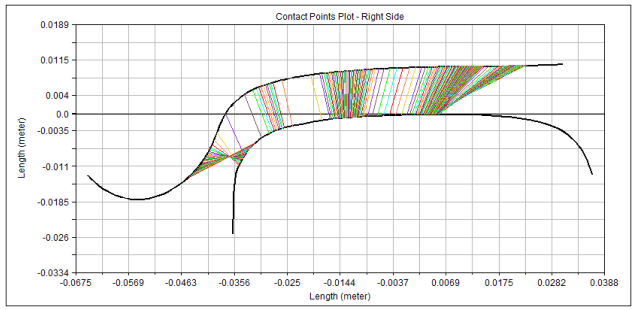
Wheel-Rail Contact Model



- No constraints, only forces
- Real flexible multi-point contact
- No boundaries in the definition of the wheel/rail properties (Not only branching of rails, switches, additional guiding rails… but also other elements like brake shoes…)





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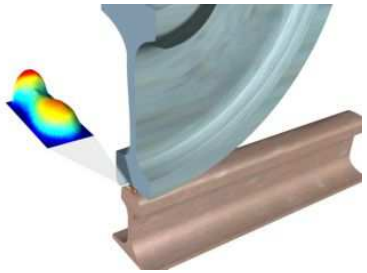
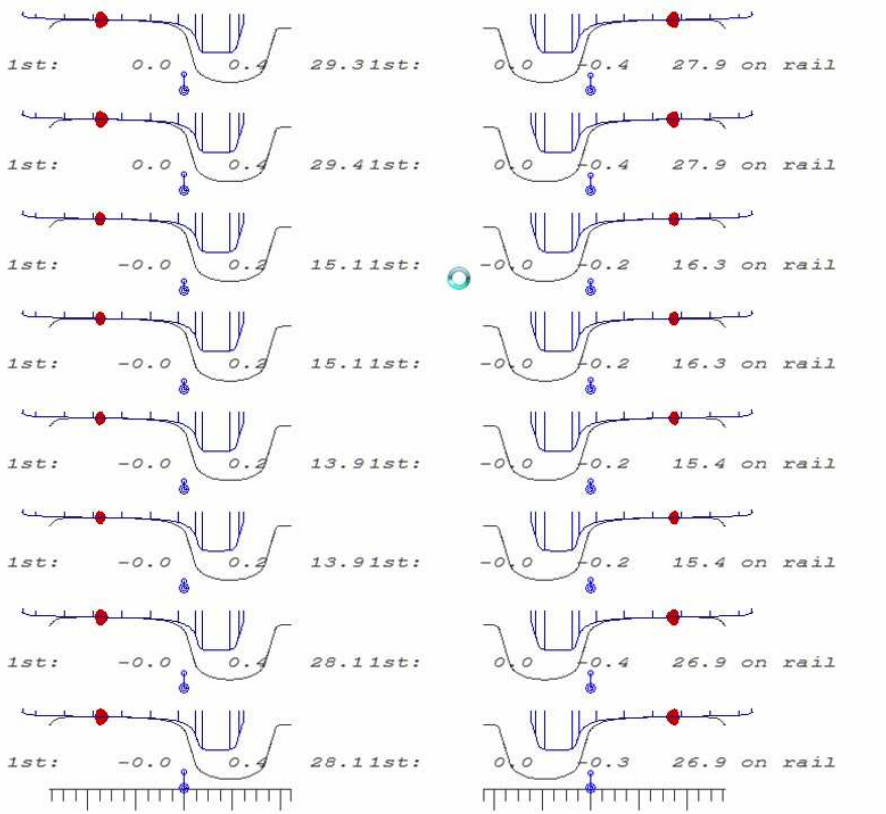
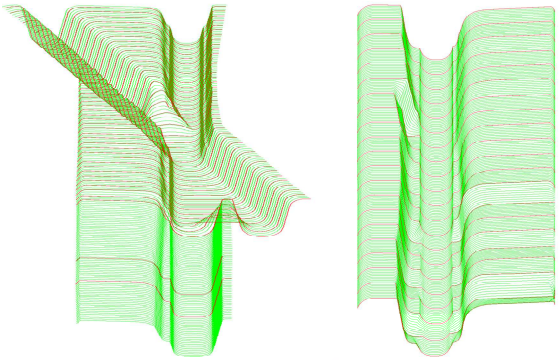
Wheel-Rail Contact Model



- Simulation of vehicle through very worn switch





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VI-Rail

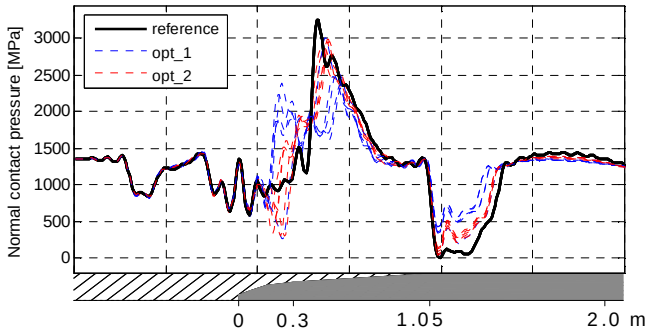
Wheel-Rail Contact Industry Validation

Challenge

- Increasing RCF damage at turnouts (counter-tendence with respect to track damage in the NL)
- 100 turnouts replaced in 1 year (6.4 Mio Eur)
- Broken crossings highly responsible for disruption times

Solution

- VI-Rail-based systematic numerical approach for improving the crossing geometry
  - Track irregularities at multiple directions
  - Flexible wheel
  - Flexible (moving) MBS-based track model



Outcome

- Parametric studies as function of:
  - Loading condition (speed, axle load, suspension system)
  - Wheel profiles (new, worn, different wheel radius… etc.)
  - Track alignment (lateral/vertical irregularities)
  - Interaction effect of multiple parameters

VI-Rail
Embedding rail-specific technology

- Enable detailed simulation of interaction between vehicles and infrastructure
  ➔ ***VI-FlexTrack***

- Embed library of freight bogies + AAR specific validation procedures
  ➔ ***VI-Rail Freight (NEW!)***

- Embed ArgeCare wear and stress toolkit into VI-Rail
  ➔ ***VI-Rail Wear + VI-Rail Stress (NEW!)***

- Embed postprocessing procedure according to EN14363 regulations
  ➔ ***VI-Rail Comfort Toolkit***

VI-Rail
VI-FlexTrack

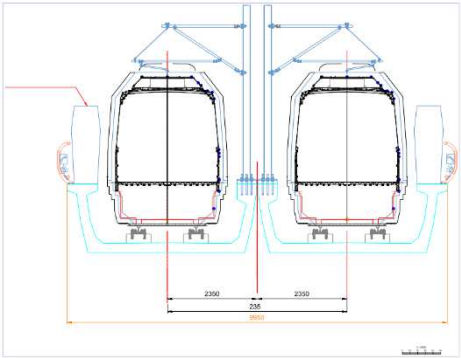
- Enables to model in detail the dynamic effect of a train passing over a rail

- Takes into account the actual wheel/rail states for the calculation of the wheel/rail contact using the general wheel/rail contact element

- *Enhanced infrastructure model comprising flexible rail beams and independent rail-sleeper and sleeper-ground connection*
  - *Introduced additional degrees of freedom at sleeper/ground and rail/sleeper interconnection for more detailed description of rail bending*
  - *Added "rail height" in the model to take in account distance between contact patch and rail to sleeper connection*
  - *Added the possibility to generate flexible track with generic infrastructure, as an alternative to the already available ballasted track*

VI-Rail

VI-FlexTrack Industry Validation

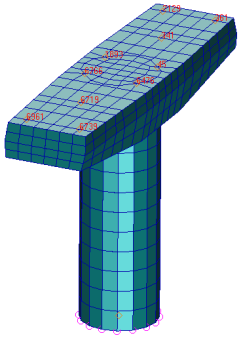


Challenge

- Determine bridge deflection and stresses on tangent track and curved track

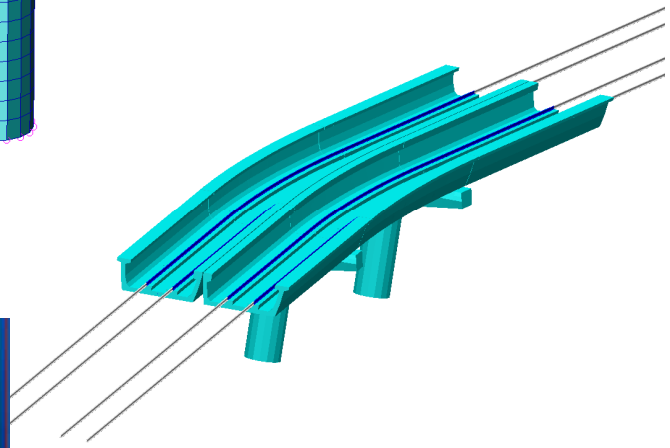
Solution

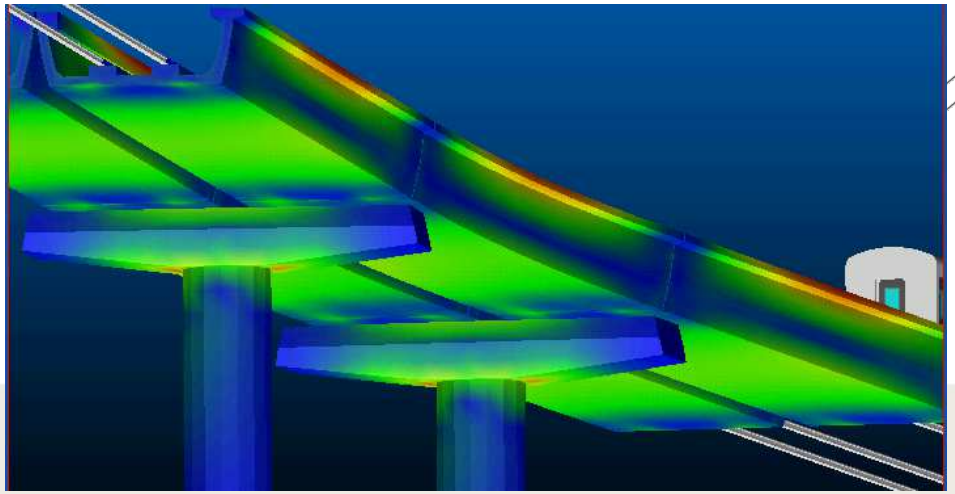
- VI-Rail + VI-FlexTrack
  - Generate CAD model, FEM model, MBD model
  - Develop a methodology for MNF generation
  - Automatically generate the flextrack



Outcome

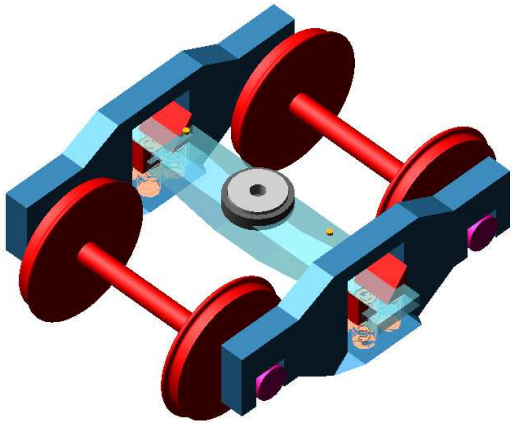
- Realistic values for displacement and stresses
- New models can be generated / evaluated in less than 3 days





VI-GRADE

VI-Rail
VI-Rail Freight

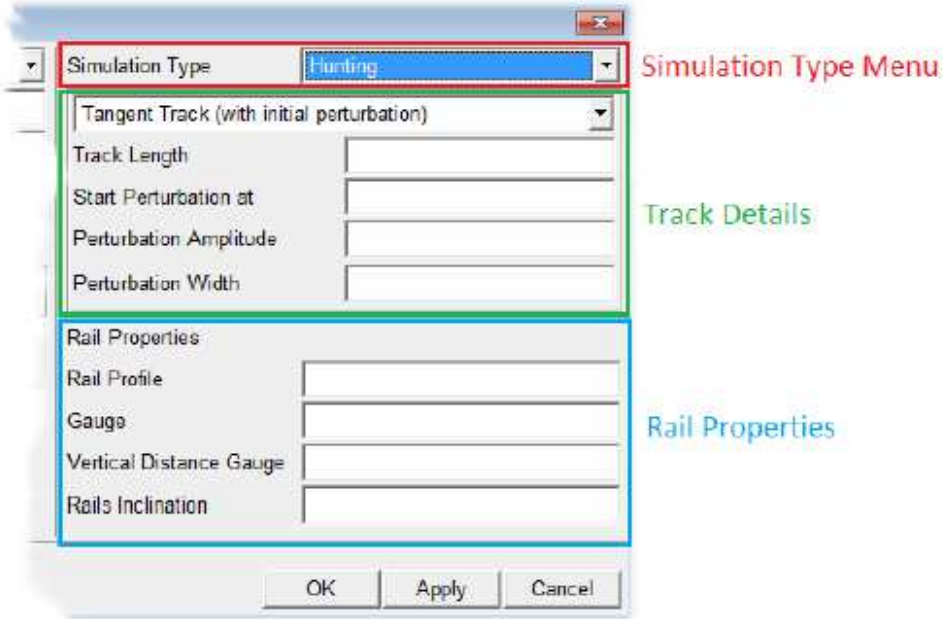


- Library of freight elements
  - Sideframe and bolster with parametric geometry
  - Bistop
  - Side Bearers
  - Centerplate with embedded planar friction torque
  - Friction Wedge with embedded planar friction force and vertical spring
  - Freight Request, designed to allow easily evaluation of the acceptance criteria established in AAR Chapter XI (2007) regulation
- Detailed, parameteric 3-piece-bogie can be created with few mouse clicks

VI-Rail

VI-Rail Freight

- Geometry according to AAR
  - Non-perturbed tracks
    - Hunting
    - Constant curve
    - Spiral
  - Perturbed tracks
    - Twist and roll
    - Pitch and bounce
    - Yaw and sway
    - Dynamic curving
- Tracks are generated on-the-fly



VI-Rail

VI-Rail Freight

- Automated procedure to process the simulation results in order to easily evaluate the acceptance criteria according to AAR regulations
- Automatic detection of analysis type, calculation of proper parameters and comparison against acceptance criteria
- Automatic report generation

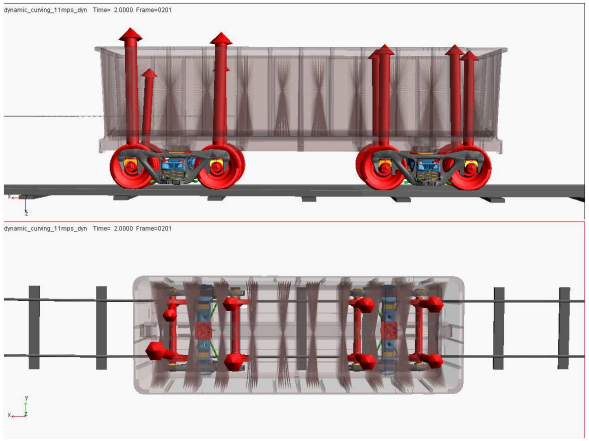


Table 11.1 Criteria for assessing the requirements for field service

Regime	Paragraph	Criterion	Limiting Value
Hunting (empty)	11.7.2	maximum lateral acceleration (g)	1.5[a]
		standard deviation of lateral acceleration (G)	0.13
Constant curving (empty and loaded)	11.7.3	95th percentile maximum wheel L/V	0.8
		95th percentile maximum axle sum L/V	1.5
Spiral (empty and loaded)	11.7.4	minimum vertical load (%)	10[b]
		maximum wheel L/V	1.0[c]
		maximum axle sum L/V	1.5[d]
Twist, roll (empty and loaded)	11.8.2	maximum roll (deg)[e]	6
		maximum axle sum L/V	1.5[d]
		minimum vertical load (%)	10[b]
		dynamic augment acceleration (G)	1.0
		loaded spring capacity maximum	95%
Pitch, bounce (loaded) (empty at EEC discretion)	11.8.3	minimum vertical load (%)	10[b]
		dynamic augment acceleration (G)	1.0
		loaded spring capacity maximum	95%
Yaw, sway (loaded)	11.8.4	maximum L/V truck side	0.6[d]
		maximum axle sum L/V	1.5[d]
Dynamic curving (empty and loaded)	11.8.5	maximum wheel L/V	1.0[c]
		maximum axle sum L/V	1.5[d]
		maximum roll (deg)[e]	6
		minimum vertical load (%)	10[b]

VI-Rail *at General Electric*

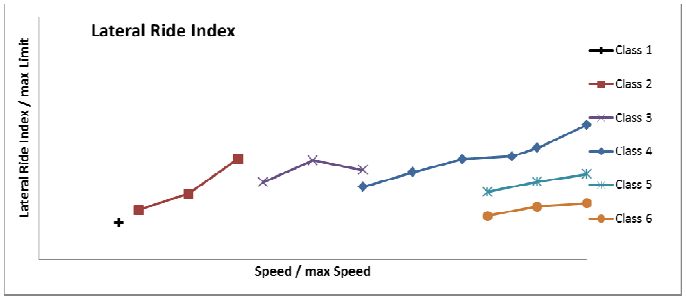
VI-Freight Industry Validation

Challenge

- Assessment of dynamic performance of the locomotive on straight track conditions with and without irregularities
- Assessment of ride quality performance and validation against the actual test condition

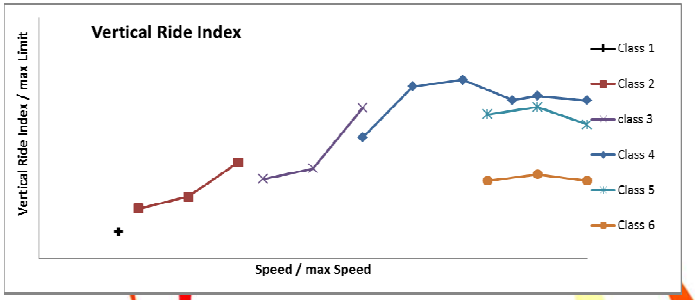
Solution

- VI-Rail + VI-Freight model with:
  - Pedestal type bogie with 3 axles
  - Axle hung traction motors arrangement
  - Casted frame with traditional brake cylinder piping arrangement
  - Secondary suspension with rubber pads
  - Primary suspension with coil springs
  - Wheel arrangement : Co –Co

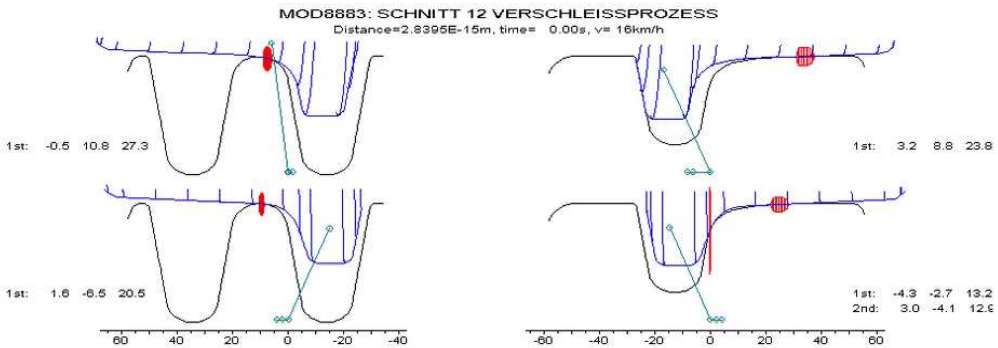


Outcome

- Simulation enabled to:
  - Assess ride quality and a range of dynamic performances
  - Compare AAR and AS standards to accomplish an Australian Standards compliant bogie design
  - Evaluate dynamic performance to comply with Australian standard in place of physical validation requirement



VI-Rail
VI-Rail Wear

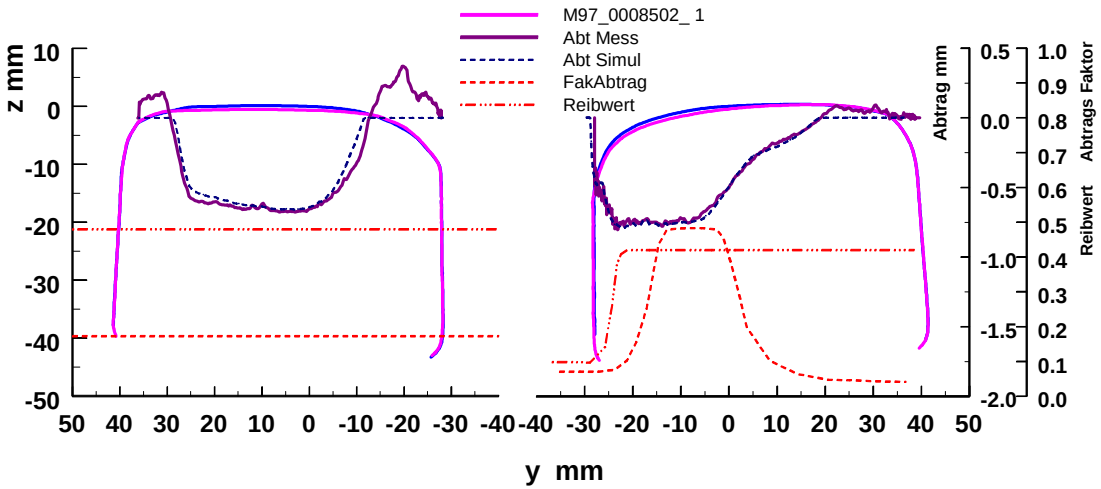


- Online wear prediction algorithm integrated within standard VI-Rail
- Can simulate wear of
  - Rail profiles – constant or variable along the track (curve, switch)
  - Wheel profiles – constant or variable along the circumference (poligonyzation)
- Based on Archard abrasive wear theory
  - Wear proportional to frictional work (calculated for each time step)
- Embedded in VI-Rail WRGEN (flexible, non elliptical, multi point) contact
- Parallel approach for the wear process
  - In each integration step, abrasion is computed and cumulated
  - At each defined event (i.e. worn area, number of steps, time increment) the resulting abrasion is used to modify the profiles
- Resulting wear is generated with several load cases, i.e.
  - Tare vs semi-laden vs. full-laden vehicle
  - Curve tracks with different curvature
  - Straight tracks with different quality

VI-Rail

VI-Rail Wear Validation

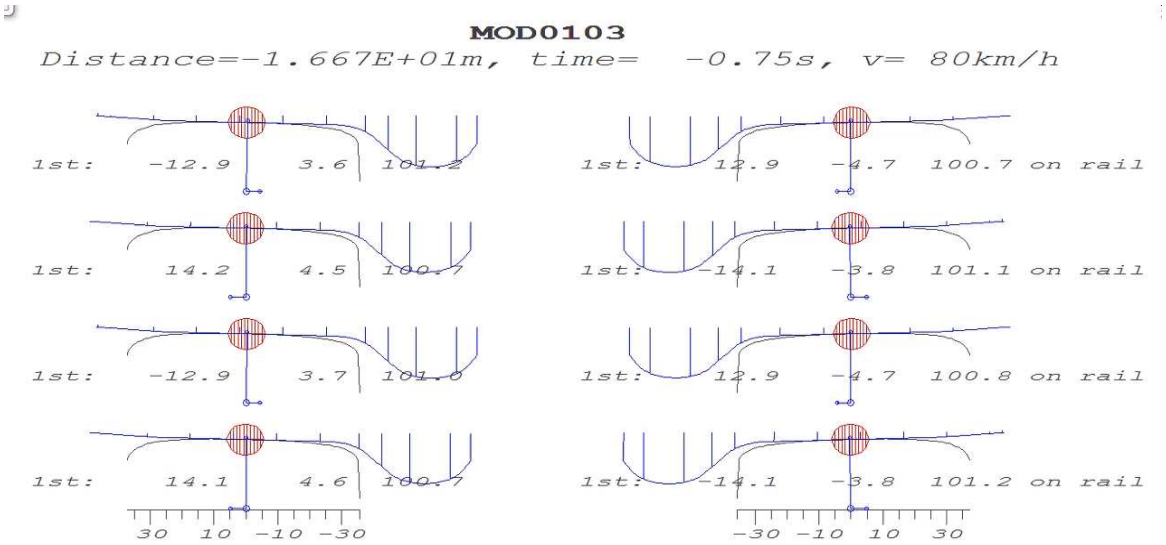
- Measurements performed by DB in 1996 and 1997 have been used to finetune the wear parameters
  - Mix of wheel profiles
  - Friction coefficient across the rail profiles
  - Wear coefficients across the rail profiles
- The defined set of wear parameters has been then used to predict wear level for 1999, in full agreement with the available measurements



VI-Rail

VI-Rail Wear Example

- Three-piece bogie (with wedges) with 1 mm difference of rolling radii
- Running on straight track with high friction coefficient
- Russian profiles



VI-Rail

VI-Wear Industry Validation

BOMBARDIER
the evolution of mobility

Challenge

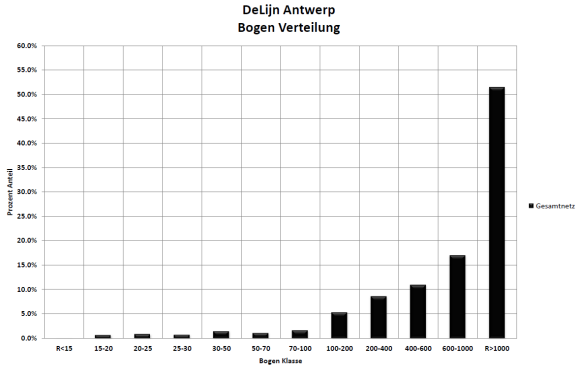
- Improvement of ride behaviour
- Increase of wheel life
- Improvement of Vehicle/Track Interaction
- Reduction of track damage
- Increase customer satisfaction

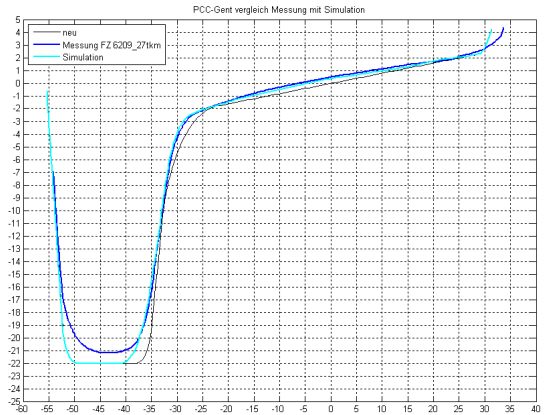
Solution

- VI-Rail plus Wear Toolkit

Outcome

- *"VI-Rail combines a superior wear calculation module with an equally superior and exquisitely user friendly multibody simulation environment.*
- *"Wear Projects are automatically grouped to respective folders making traceability better.*
- *"The work carried out over the past few months with VI-Rail has validated real-life measurements to wear computations.*
- *"Worth noting is the robustness, speed and precision of the acompanying solver during wear calculations even at large sample rates"*





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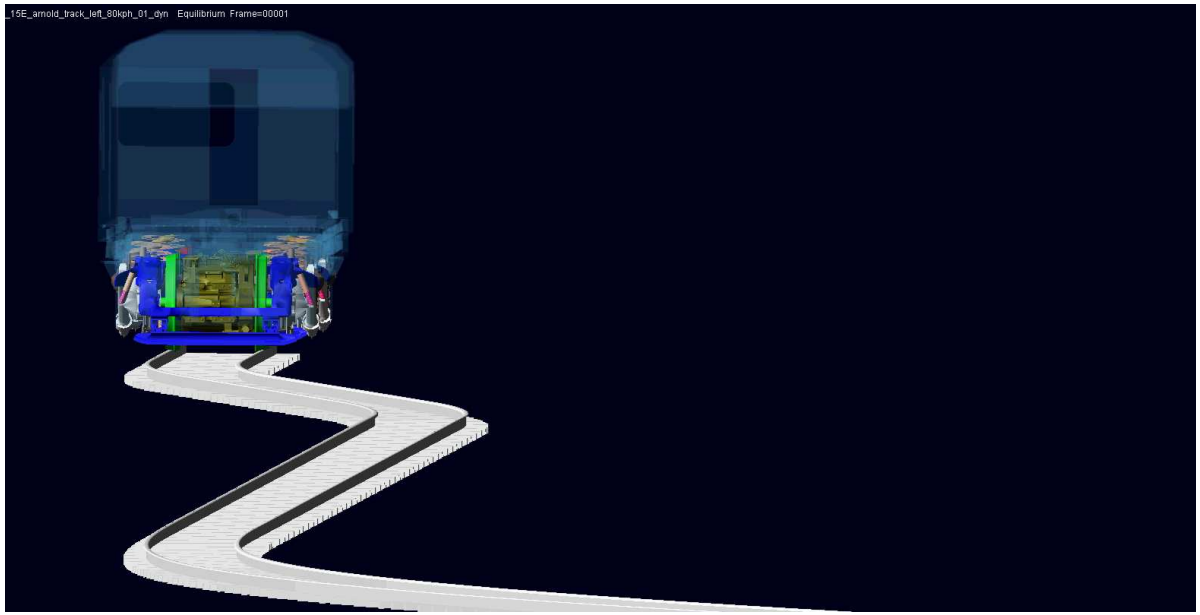
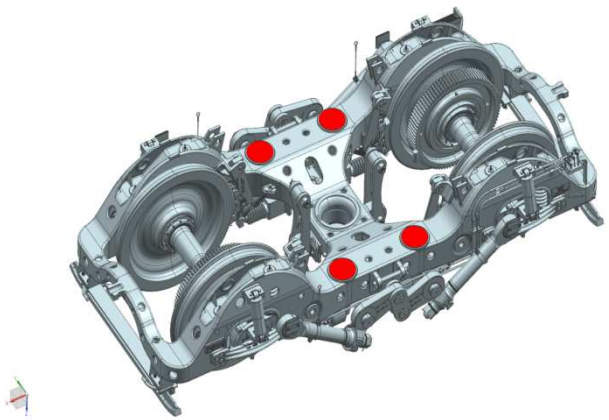
VI-Rail
Solving operational problems

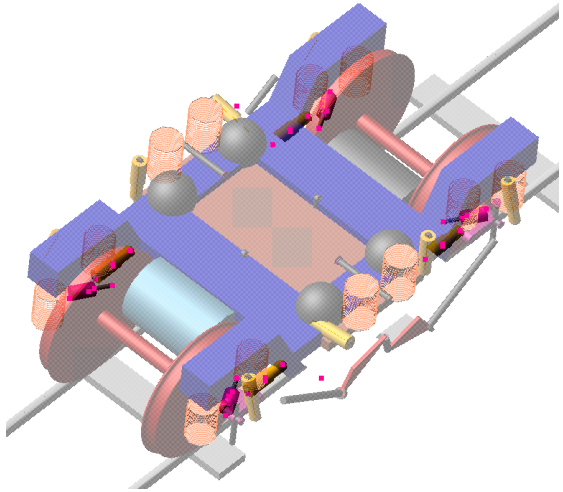
- Used VI-Rail to investigate and solve unsymmetrical wheel wear on 15E locomotive (part of the longest production train in the world over a distance of 860 km)



VI-Rail
Solving operational problems

- Used VI-Rail to improve curving performance of 19E locomotive, matching wheel wear rates to minor overall cycle (6 year) and to investigate the possible improvement in curving performance in tight curves using passive hydraulic systems





VI-Rail

VI-Rail Stress ***(NEW!)***

- VI-Rail add-on that allows the computation of surface stresses at wheel/rail contact interface, as well as subsurface stresses distribution in wheel and rail material in proximity of the contact patch (based on the Boundary Element Method developed by J. J. Kalker)

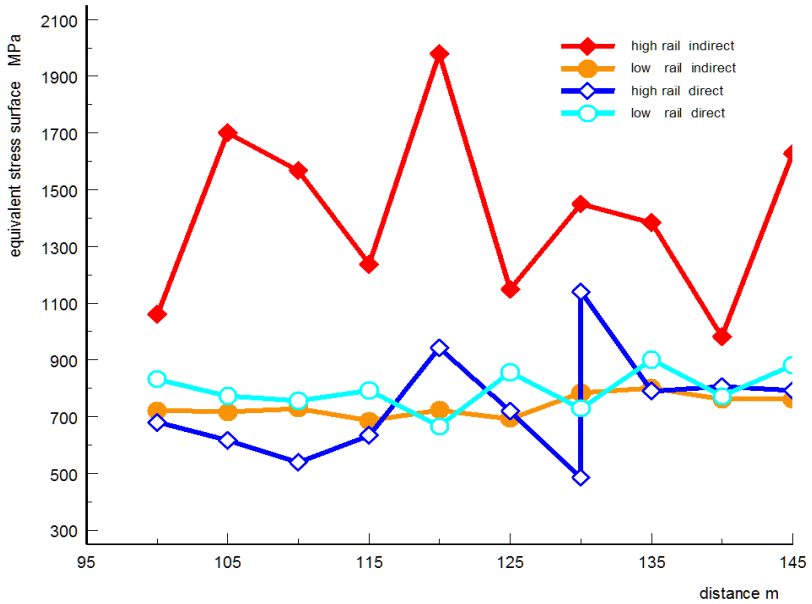
- The data needed for stress computation are generated by the contact algorithm during the dynamic analysis

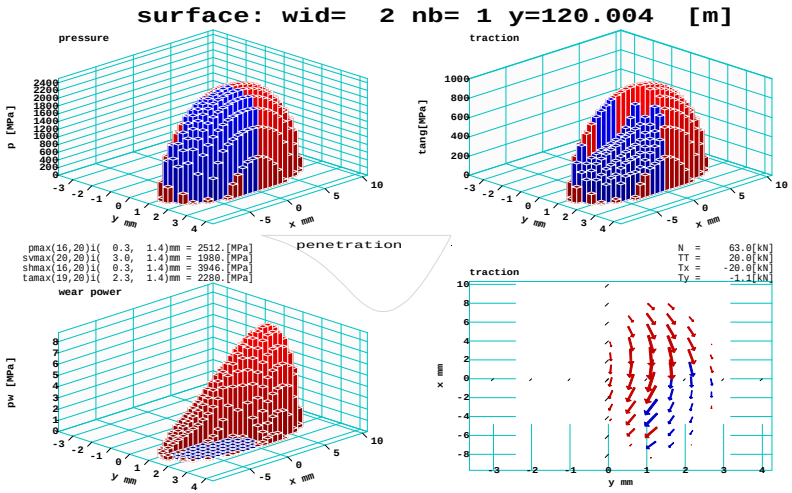
- Snapshots of the wheel-rail contact are taken at user specified positions during the dynamic analysis and are stored in ASCII files. The postprocessing of these files is performed trough the ArgeCare Stress Analysis program, which produces output in tabular and graphical formats

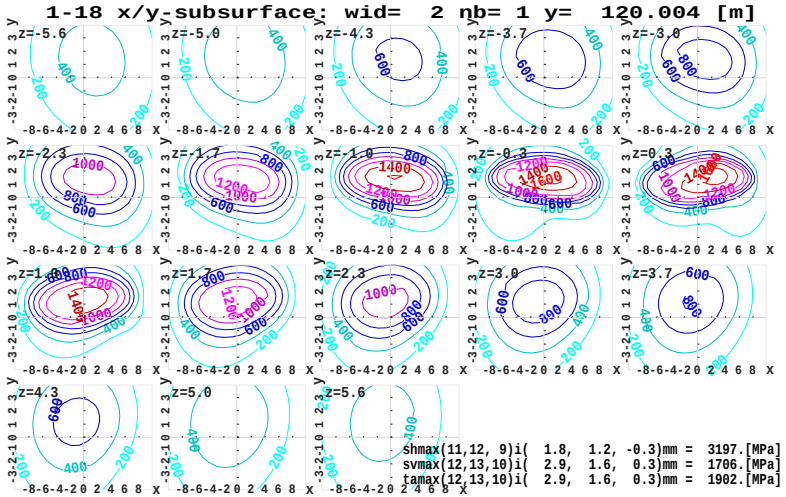
VI-Rail

VI-Rail Stress *(NEW!)*

- Surface vs subsurface contact stress evaluation

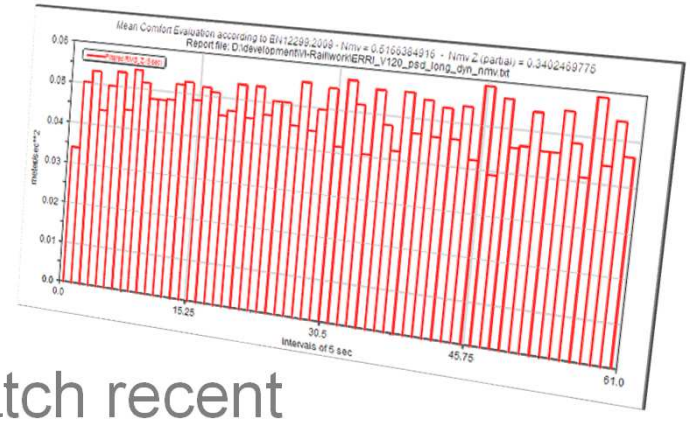






VI-Rail

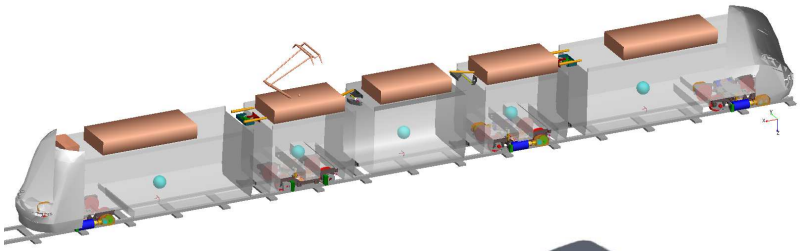
VI-Rail Comfort Toolkit



- Updated existing procedures to match recent regulations on railway comfort and added evaluation of additional comfort indices
  - Mean Comfort Index EN 12299:2009
  - Comfort on Curve Transition Index (PCT) - EN 12299:2009
  - Ride Quality and Comfort with Ride Index (Wz)
  - Comfort evaluation According to ISO2631
- Added automatic generation of report files, including main simulation statistics together with index evaluation

VI-Rail

Corporate tool for Skoda



Challenge

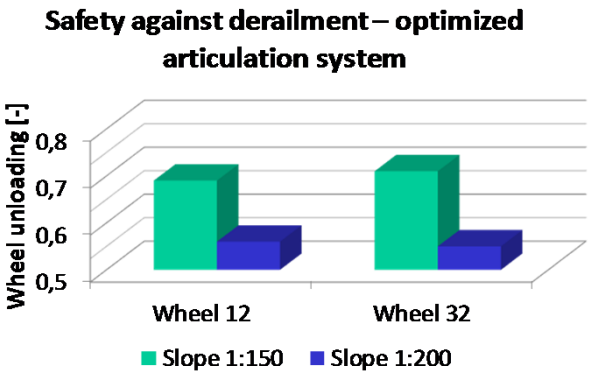
- Optimize process of five-section tram during development which began at the end of 2012, with particular attention to articulation system

Solution

- Use of VI-Rail to validate the virtual behavior of vehicle with standard and optimized articulation system

Outcome

- Optimized vehicle fulfills regulation requirements for:
  - Clearance
  - Vehicle stability
  - Curving negotiation
  - Ride and comfort



VI-Rail
Conclusions

- Solid and mature product
  - Basis established in 1995
  - Relies on ADAMS foundation
- Real general-purpose railway simulations
  - Standard railway dynamics
  - Advanced simulation scenarios
  - From component-level to system-level
- Continuous development through
  - embed of 3rd party solutions and competence
  - internal development activities
- Steadily increasing customer base
  - Loyal customers on a worldwide basis
  - New customers / addition to existing customers
- All technical papers referenced in the presentation are available for free download on www.vi-grade.com (2014 and 2015 International VI-grade Users Conference)
- ***For additional info: send e-mail to rail@vi-grade.com***