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# Enhancing Software Tools for Vehicle Dynamics and the Validation for Rail Vehicle Engineering

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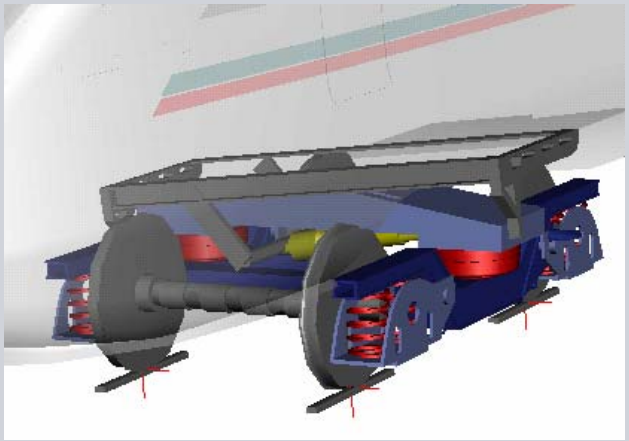
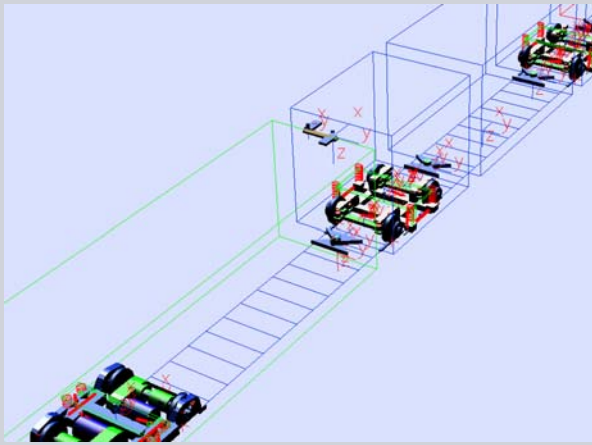
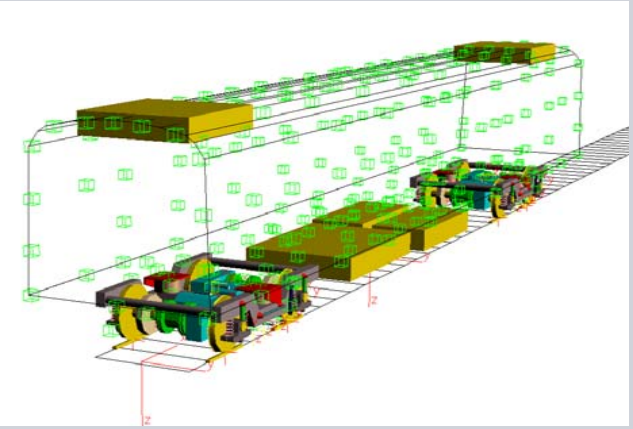
# History of major development steps

| 1994 | 2000 | 2007 |
|---|---|---|
| Nonlinear kinematics | Flexible body simulation | New SIMPACK Rail |







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# In a nutshell: Why a new SIMPACK Rail?

Easy to use:

- Input parameters: only geometric and material data
- Arbitrary number and position of contact patches, automatically handled
- Compatible with substitution variables and substructures
- Open kinematic tree structure
- Detailed outputs for vehicle dynamics and rail-wheel contact specialists
- “What you see is what you get”

Open for the future:

- State-of-the-art: equivalent elastic contact – „close to the reality“
- In preparation: non-elliptic contact patches – realistic wear/RCF simulation
- Modern data structure
- Modular programming

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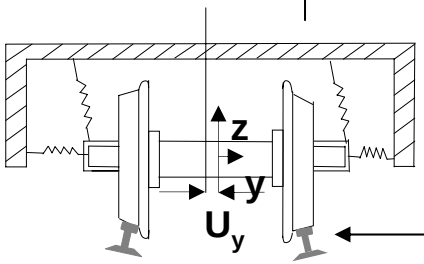
# Modeling methods

- Position
- Velocity
- Rotation angle
- Angular velocity

**Profile geometry**
Profile approximation (splines)
Calculation of the contact points

- rigid
- quasi elastic
- equivalent elastic
- discrete elastic




**Normal contact**
Normal force calculation

- Positions of the contact points

- linear
- Hertz
- non-elliptic (discrete)

See workshop!

- linear
- Johnson/ Vermeulen
- …
- FASTSIM
- non-elliptic (discrete)

**Tangential contact**
Calculation of the creep forces

- Contact area
- Normal stress distribution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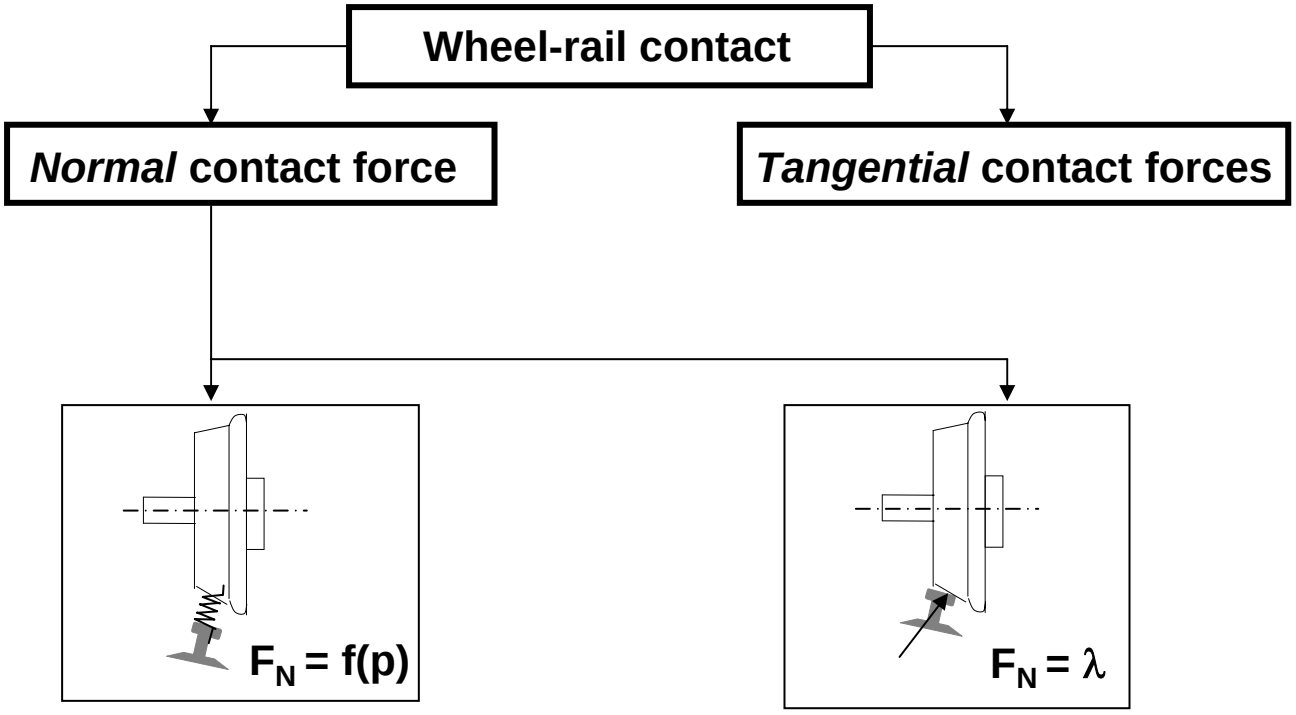
# Two different approaches: elastic or constraint model




Spring (+ damper)

Constraint

Contact search:
equivalent elastic / discrete elastic (non-elliptic)

Contact search:
quasi elastic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# Contact methods compared here

Classic SIMPACK Rail:

- *Quasi elastic* contact point search (onepoint / multipoint)
- *Constraint* normal force
- *FASTSIM* tangential forces

New SIMPACK Rail:

- *Equivalent elastic* contact point search (always multipoint)
- *Hertzian* normal force
- *FASTSIM* tangential forces

Additionally, for non-elliptic contact:

- *Discrete elastic* contact point search (always multipoint)
- *Discrete elastic* normal force
- *Discrete* tangential forces


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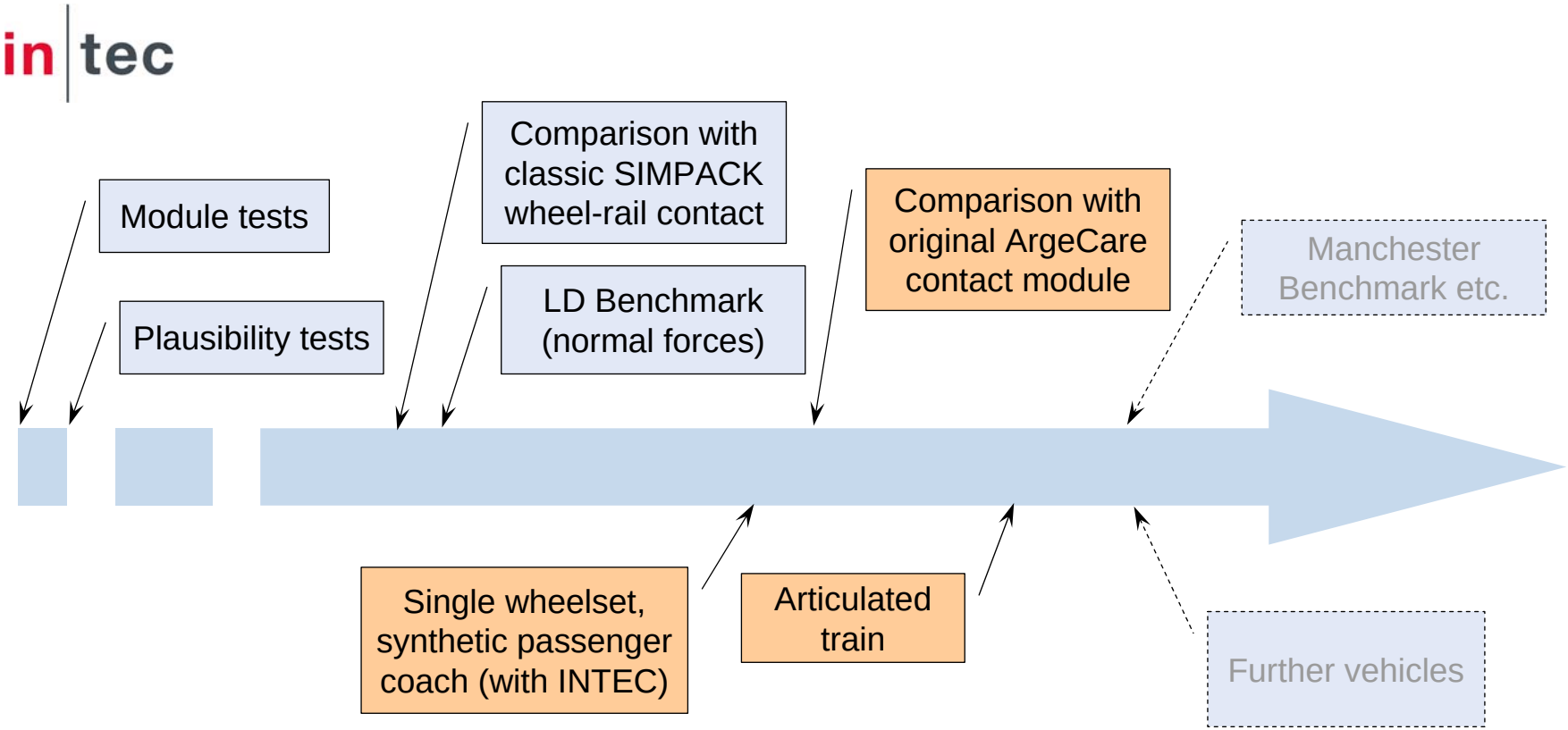
# Verification process

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# Verification models: single wheelset

Verification: *Basic* rail-wheel contact behavior

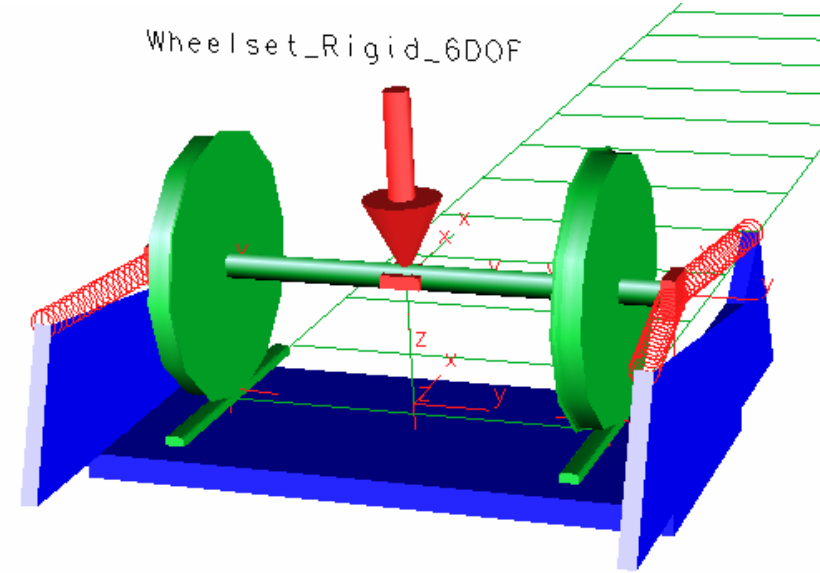
Model: Single wheelset guided by springs and dampers (derived from IAVSD Benchmark, 1991)

Scenarios: *Non-linear:*

- limit cycles and critical speed
- quasistatic flanging by lateral force and yaw torque
- deterministic irregularities in tangent track
- braking

*Linear:*

- root loci and critical speed





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# Verification models: synthetic passenger coach

Verification: Influence of rail-wheel contact upon the *full vehicle*

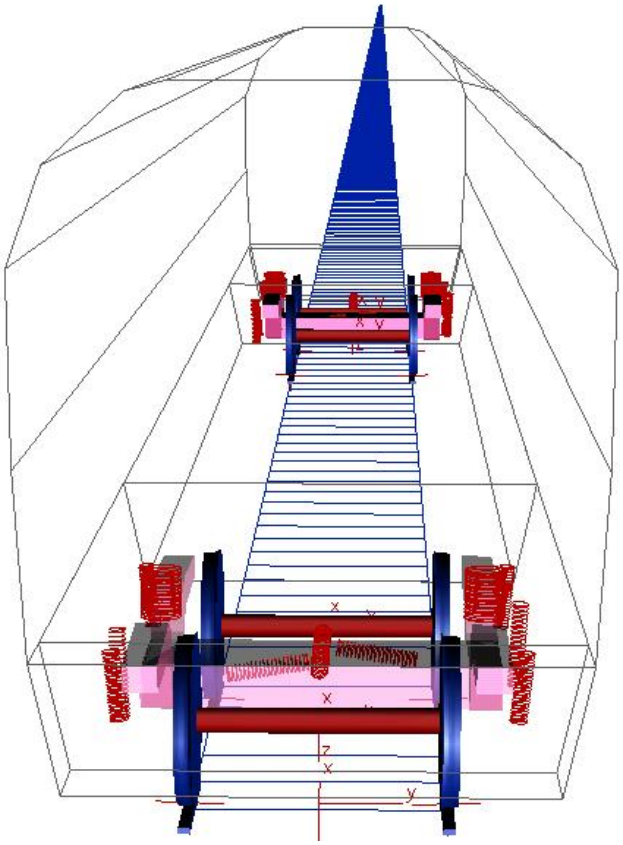
Model: Simplified passenger coach with basic damping

Scenarios: *Non-linear:*

- quasistatic flanging in curves
- deterministic and stochastic irregularities
- narrow curve, S-curve
- limit cycles and critical speed
- braking

*Linear:*

- root loci and critical speed
- frequency response, comfort

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# Verification models: articulated train

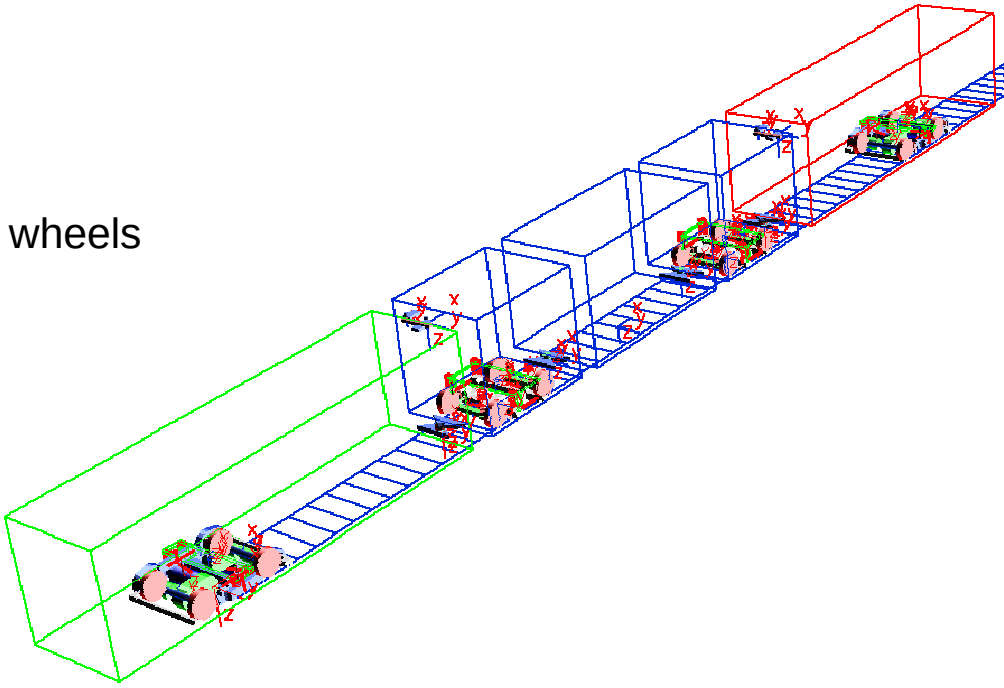
Verification: Behavior of a *realistic* vehicle

Model: Articulated train:

- 96 degrees of freedom
- 175 force elements
- 2 bogies with wheelsets
- 2 bogies with independent wheels
- 1 suspended car body

Scenarios: *Non-linear:*

- low-speed narrow curve with twist
- high-speed curve with unbalanced lateral acceleration
- tangent track with stochastic irregularities
- S-curve

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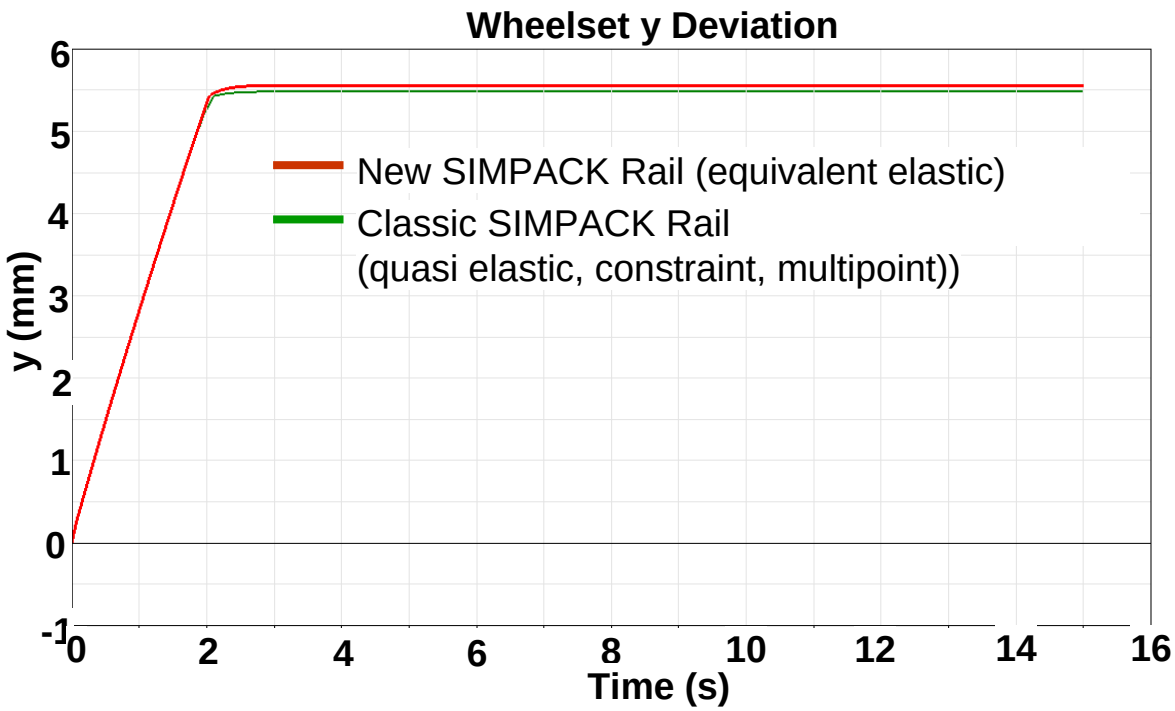
# Single wheelset – quasistatic flanging

Why: Most basic behavior of a wheelset but of crucial importance for curving

How:
- tangent track
- constant lateral force
- constant yaw torque

Results:
- contact point positions (lateral, longitudinal)
- number of contacts
- wheelset lateral position
- wheelset yaw angle
- *Y* forces




***Good agreement***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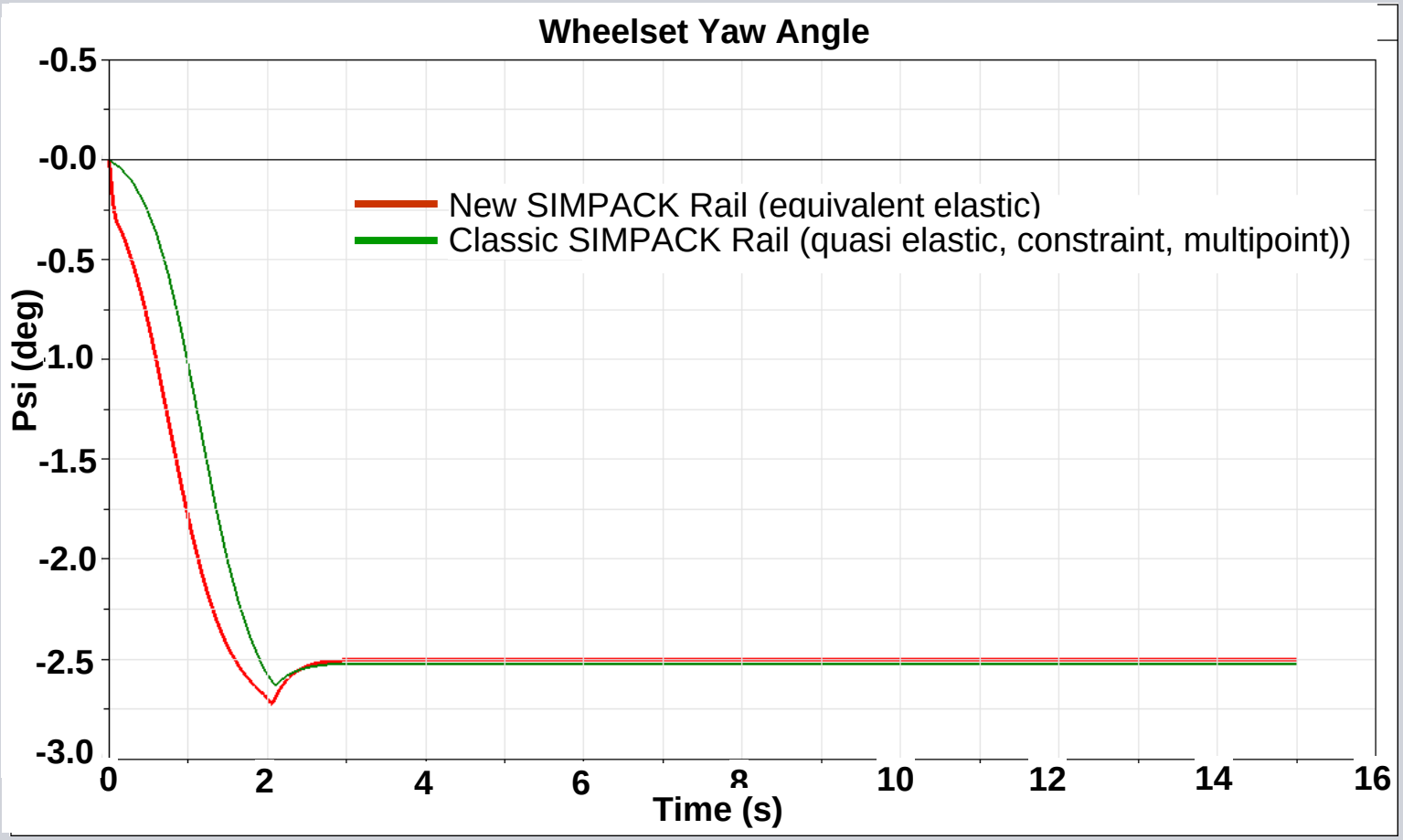
# Single wheelset – quasistatic flanging

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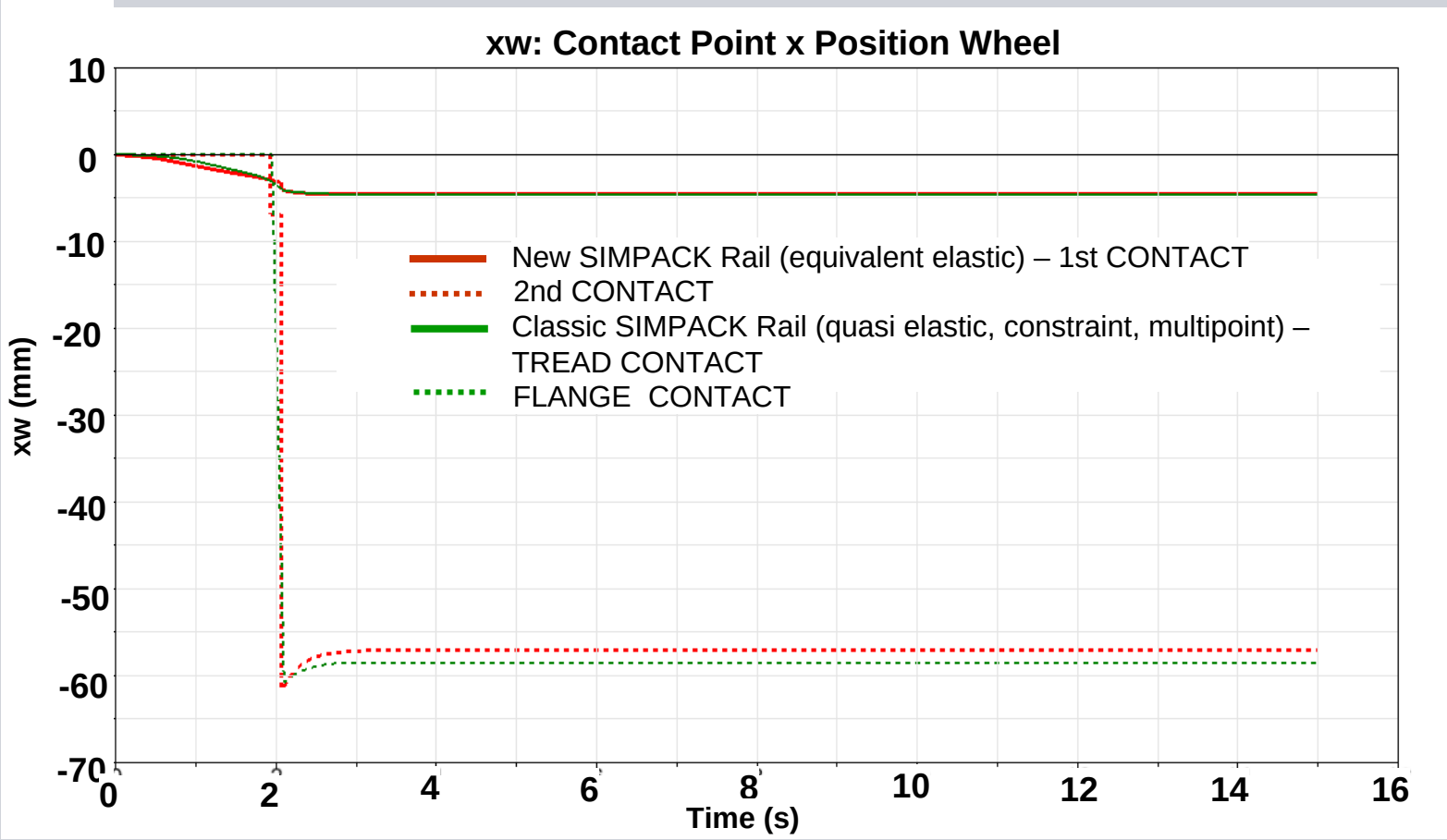
# Single wheelset – quasistatic flanging




***Flange contact positions are slightly different (elastic/constraint).***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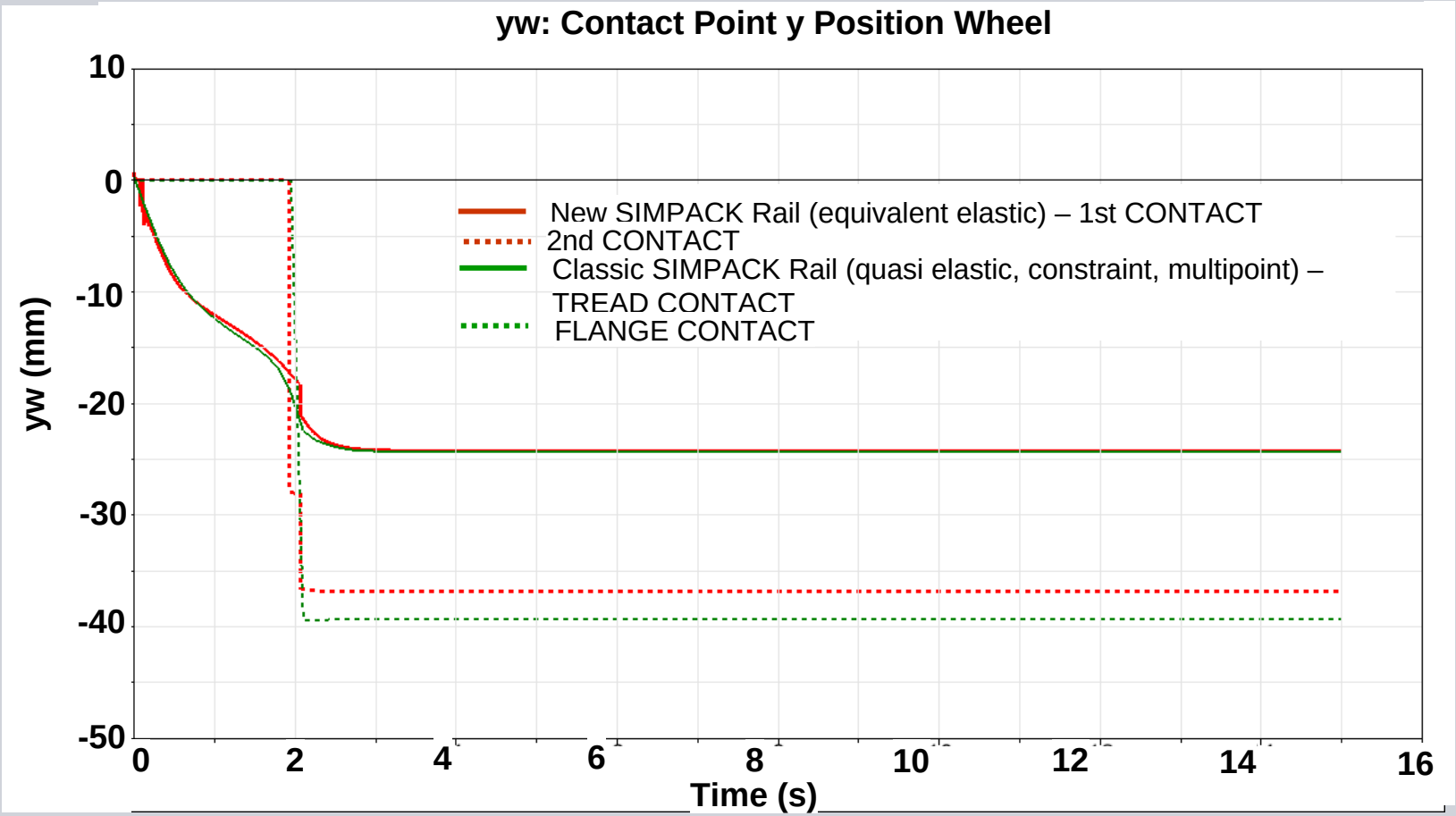
# Single wheelset – quasistatic flanging

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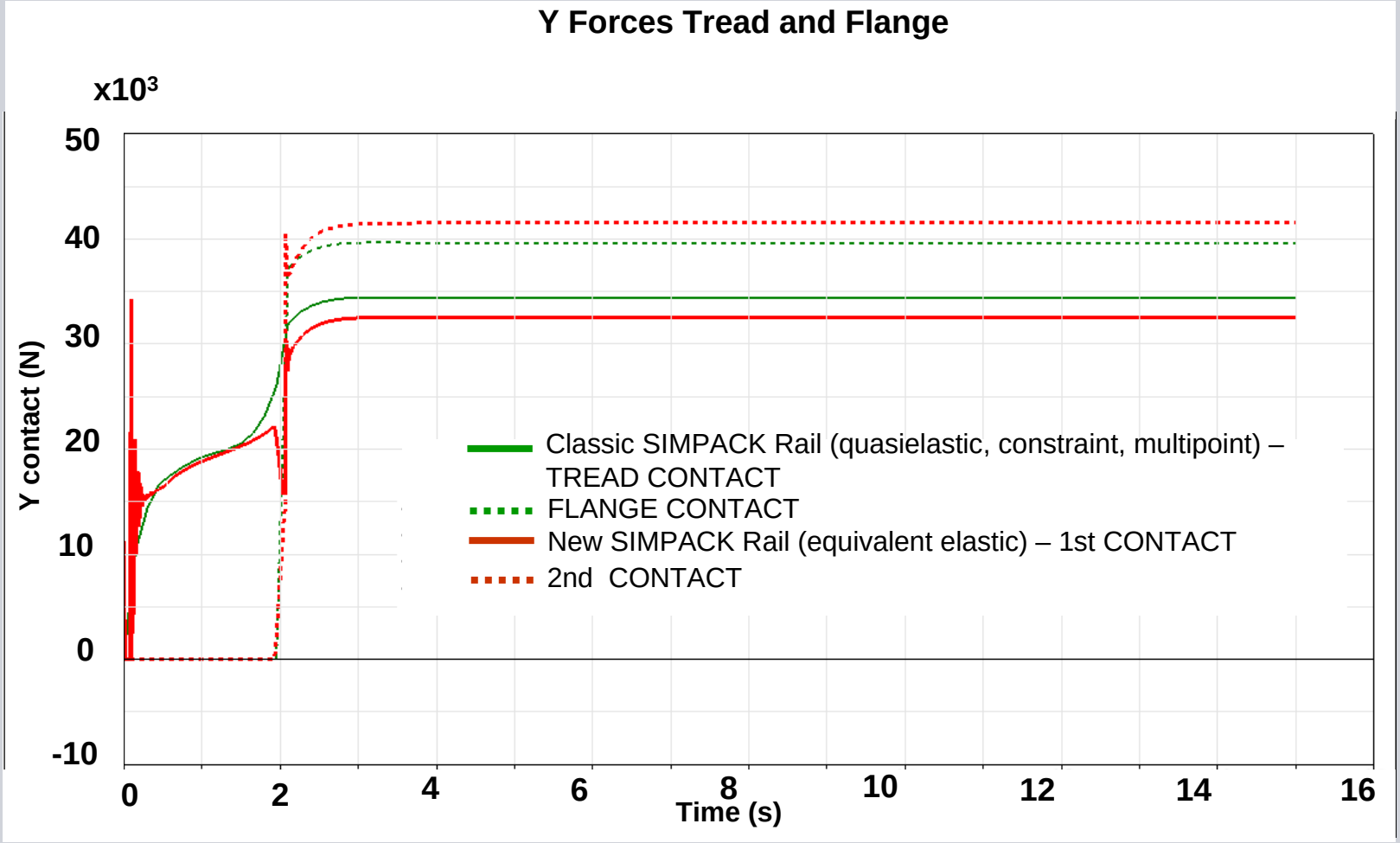
# Single wheelset – quasistatic flanging




***Y forces are slightly different (elastic/constraint).***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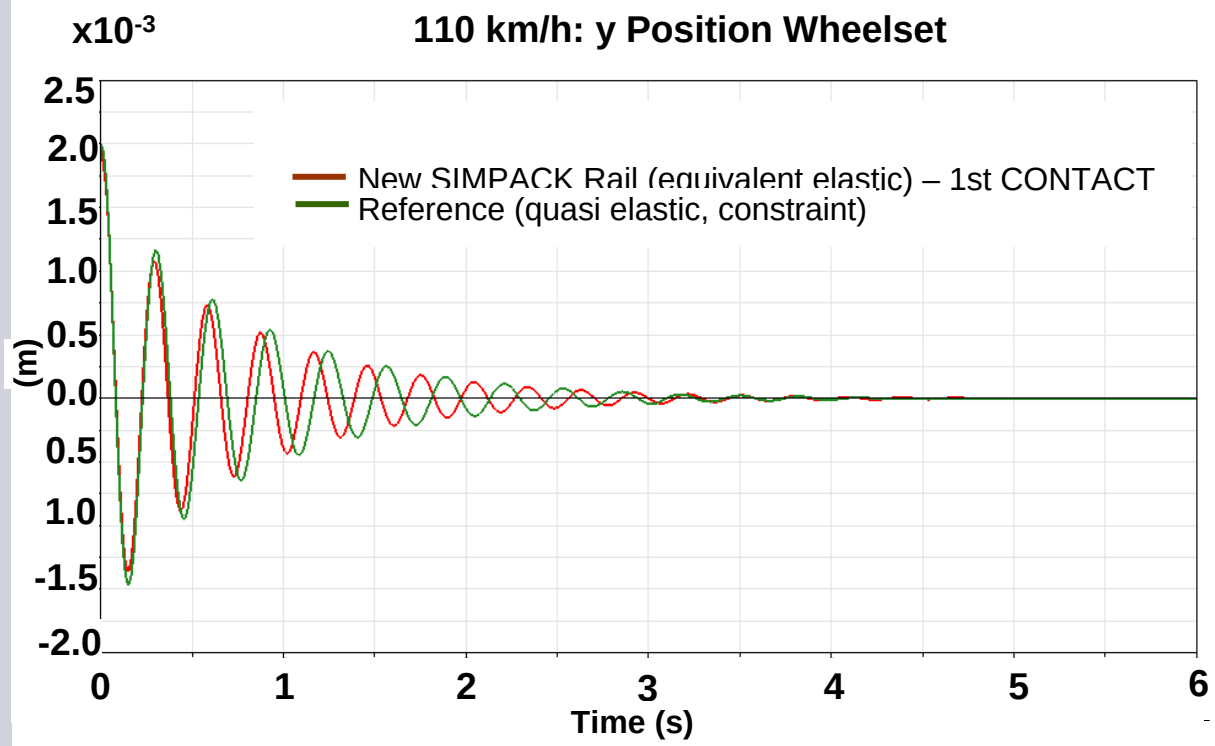
# Synthetic passenger coach – limit cycle, critical speed

Why: $v_{crit}$ is very sensitive against differences in modeling and methods

How:

- tangent track
- initial excitation
- several increasing velocities
- re-use end states for new run
- non-linear simulation

Results: Amplitudes of the wheelset after 6 s





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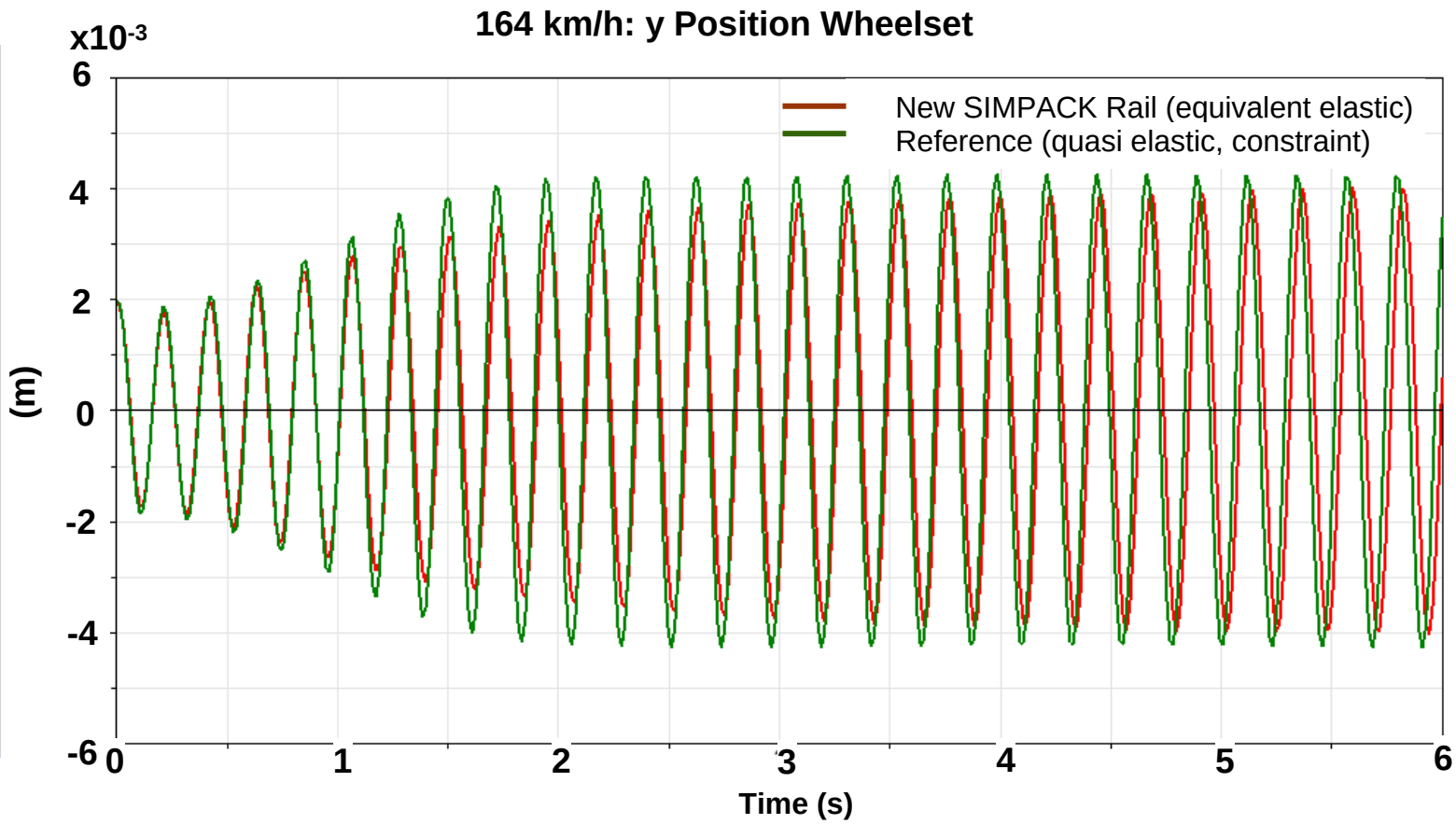
# Synthetic passenger coach – limit cycle, critical speed





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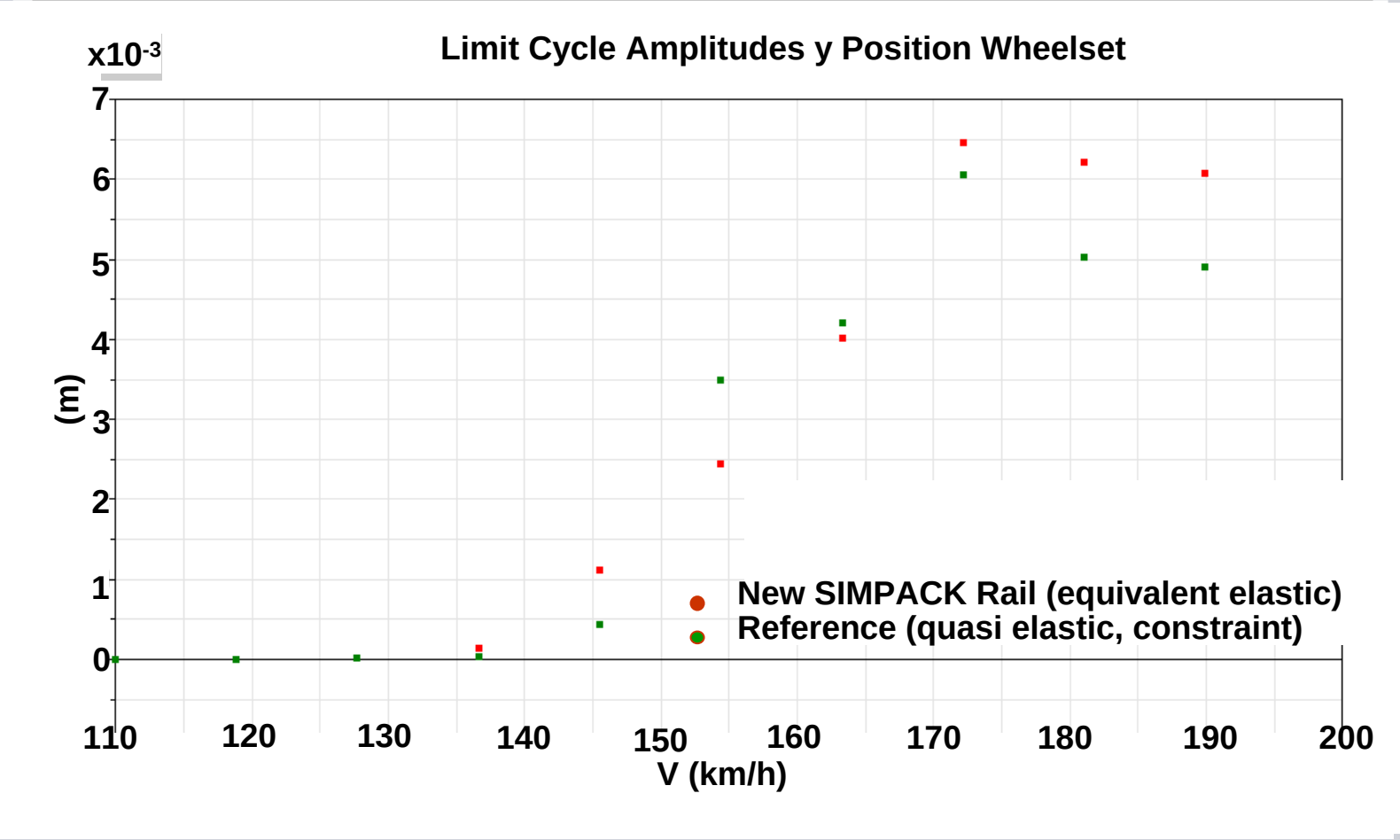
# Synthetic passenger coach – limit cycle, critical speed

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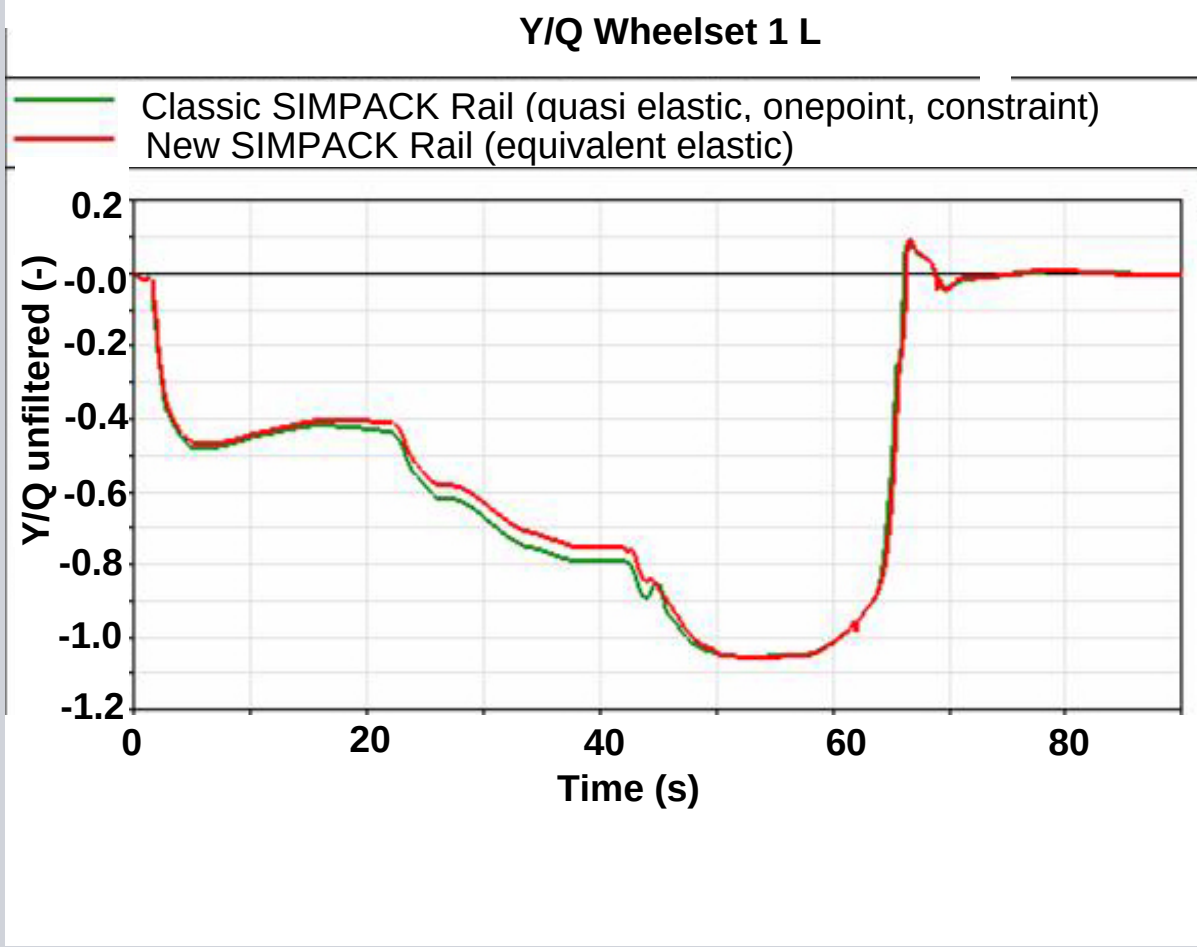
# Articulated train – narrow curve with twist

Why: Important for derailment behavior, crucial for light rail vehicles

How:
- narrow curve (*R* 20 m) with entry and exit
- large superelevation with entry/exit ramps
- low speed (quasistatic)
- large $\mu = 0.4$

Results:
- contact point positions
- number of contacts
- *Y/Q* derailment safety indicator




**Good agreement in Y/Q**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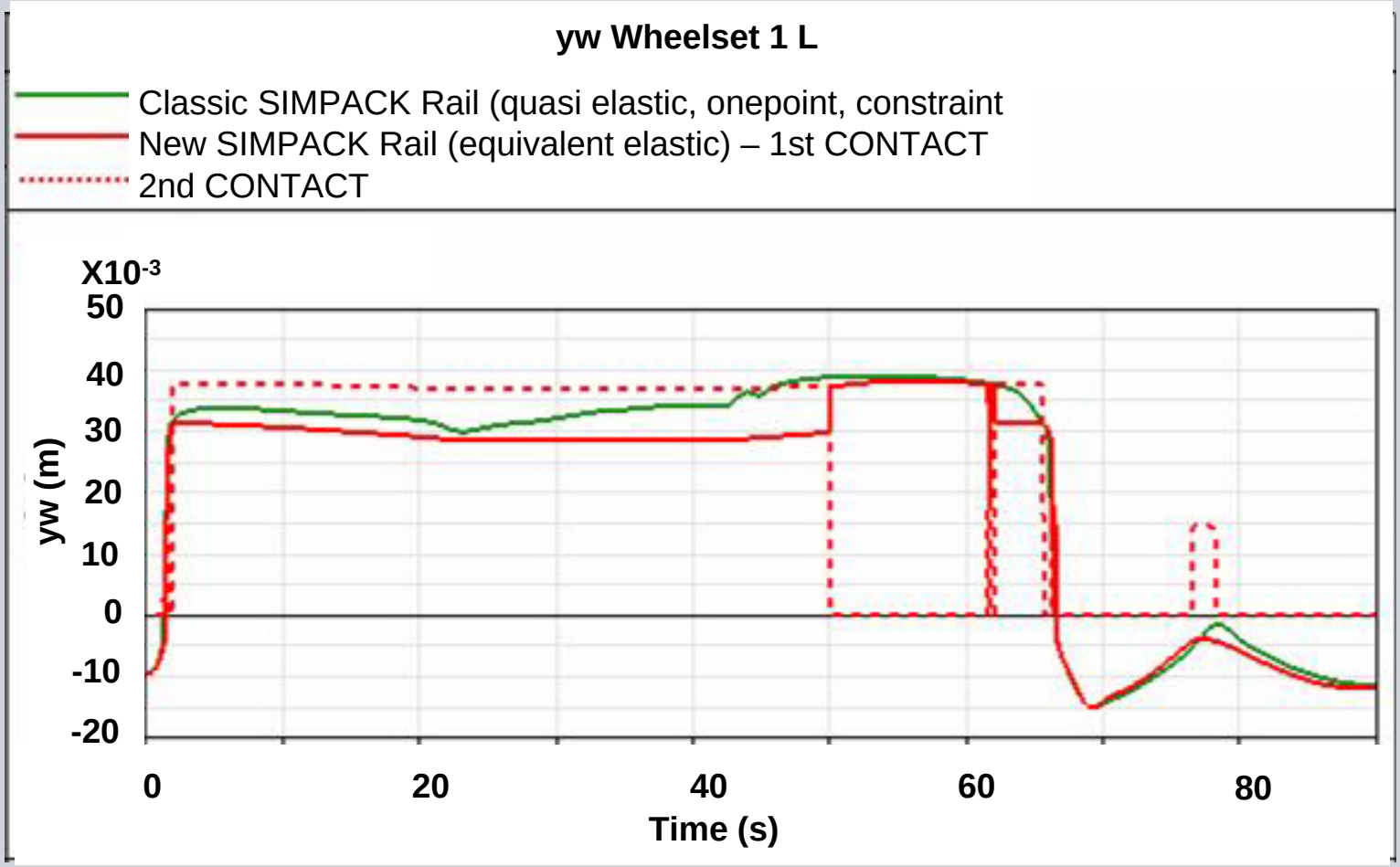
# Articulated train – narrow curve with twist




**Additional contact patches are found on flange <u>and</u> tread.**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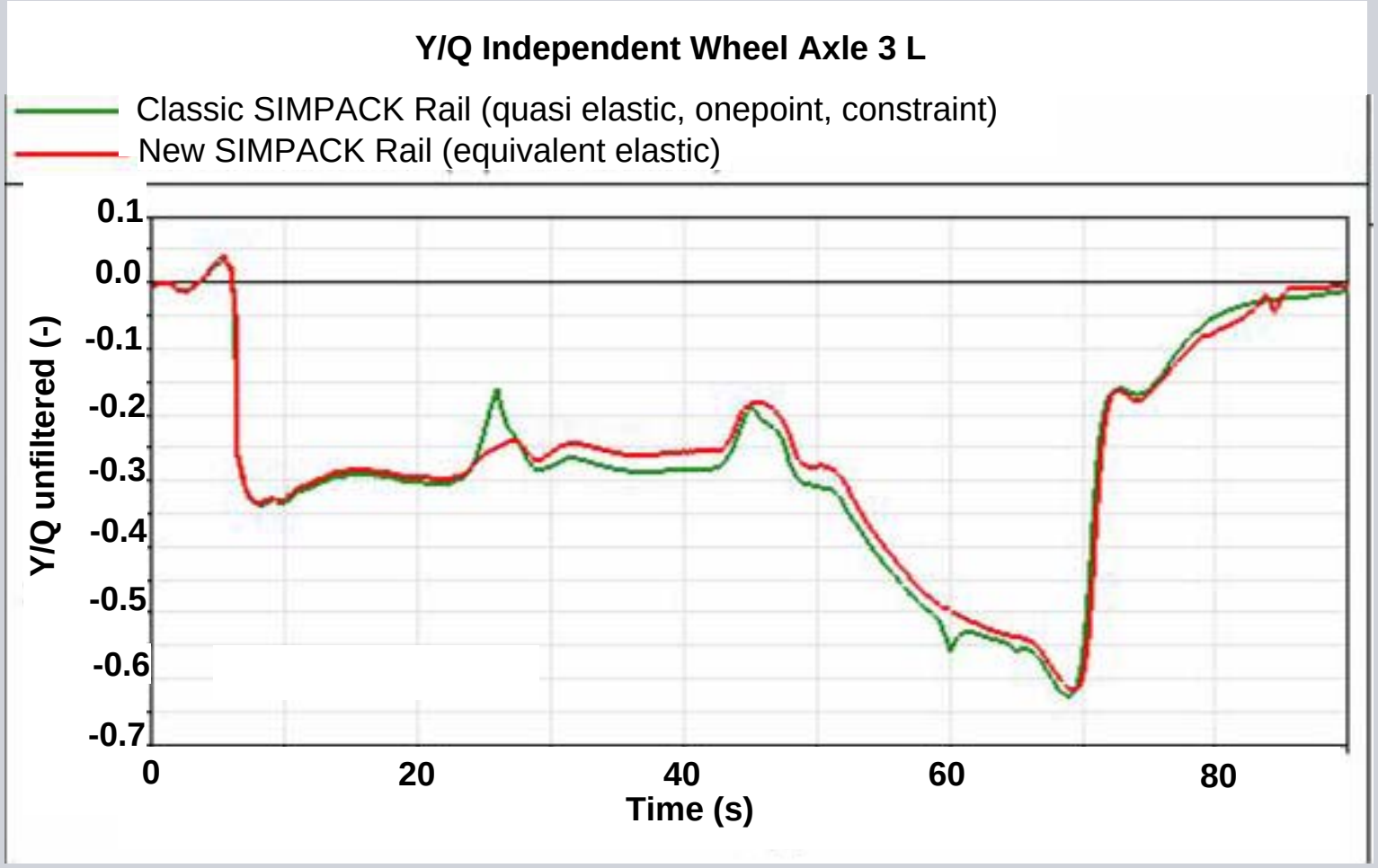
# Articulated train – narrow curve with twist

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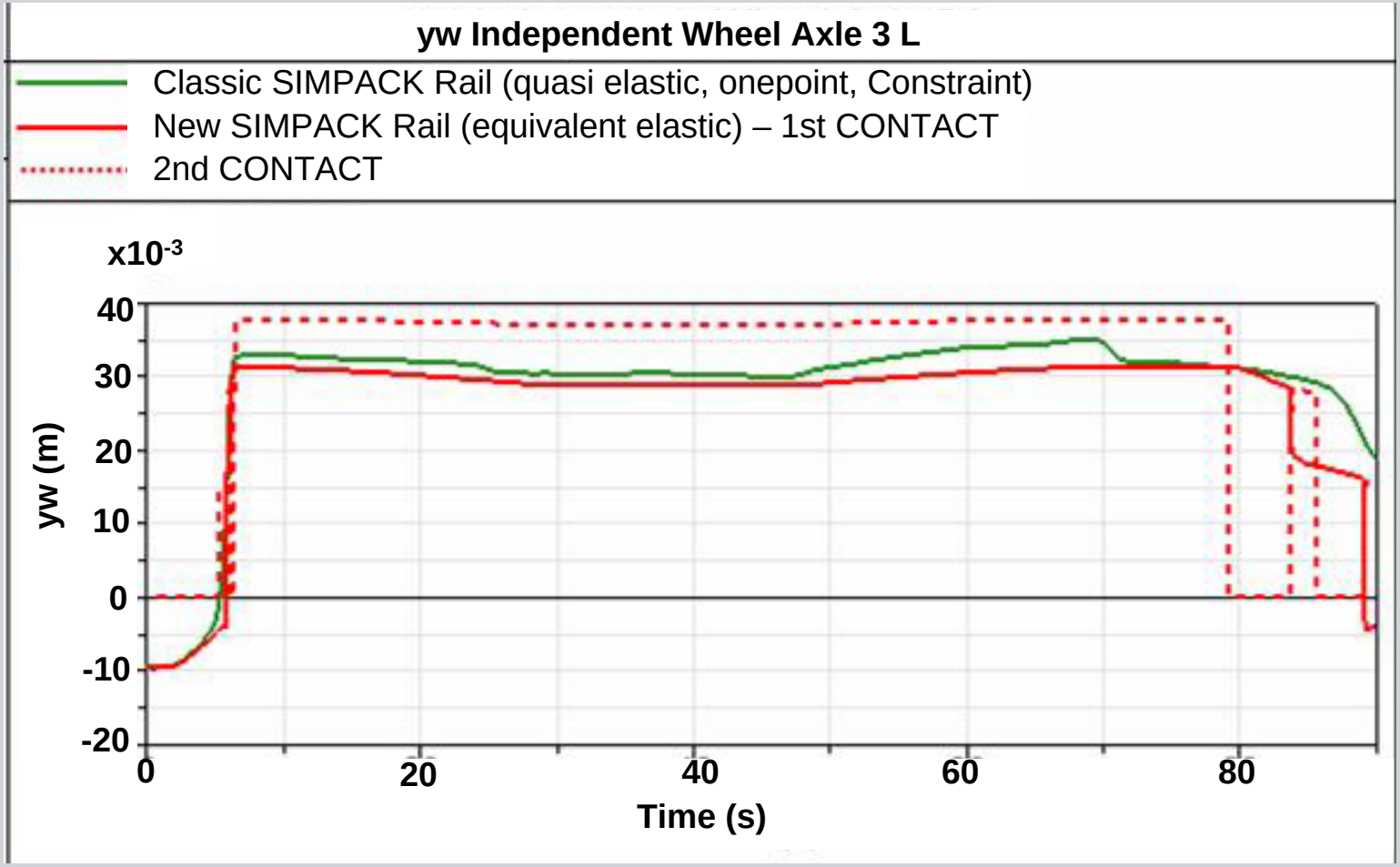
# Articulated train – narrow curve with twist




**Additional contact patches are found on flange and tread.**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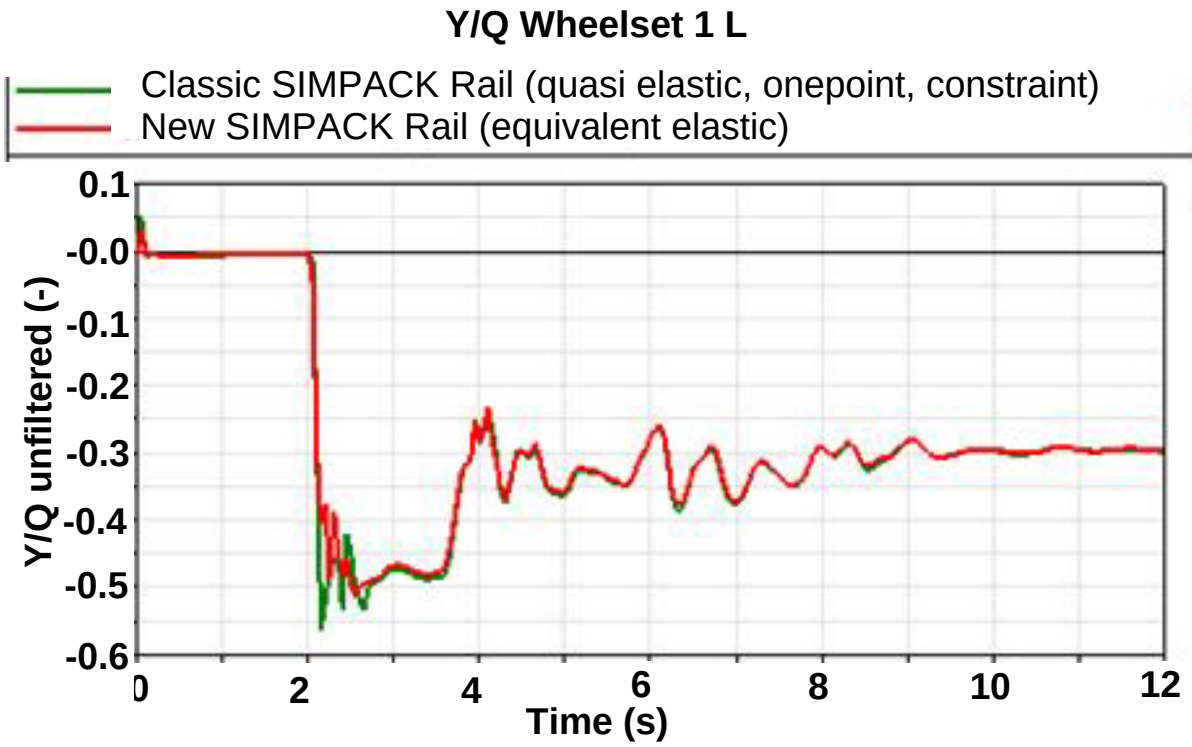
# Articulated train – large unbalanced lateral acceleration

Why: Important for derailment behavior and wheel-rail forces

How:
- curve entry and exit
- $a_q$ = 1.4 m/s²
- $\mu$ = 0.1

Results:
- contact point positions
- *Y/Q* derailment safety indicator




**Good agreement in Y/Q. Peak at curve entry is different.**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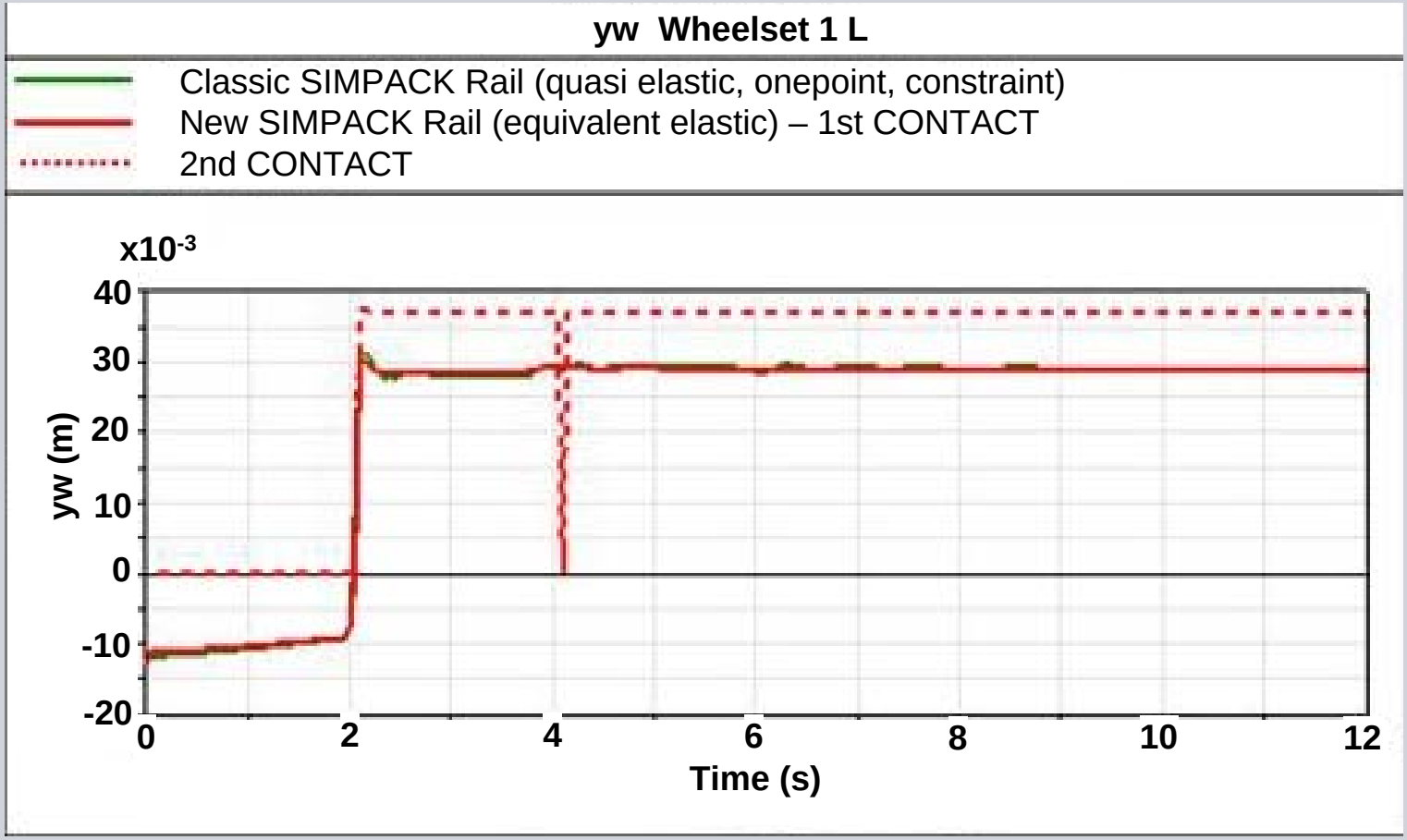
# Articulated train – large unbalanced lateral acceleration




**Additional contact patches are found.**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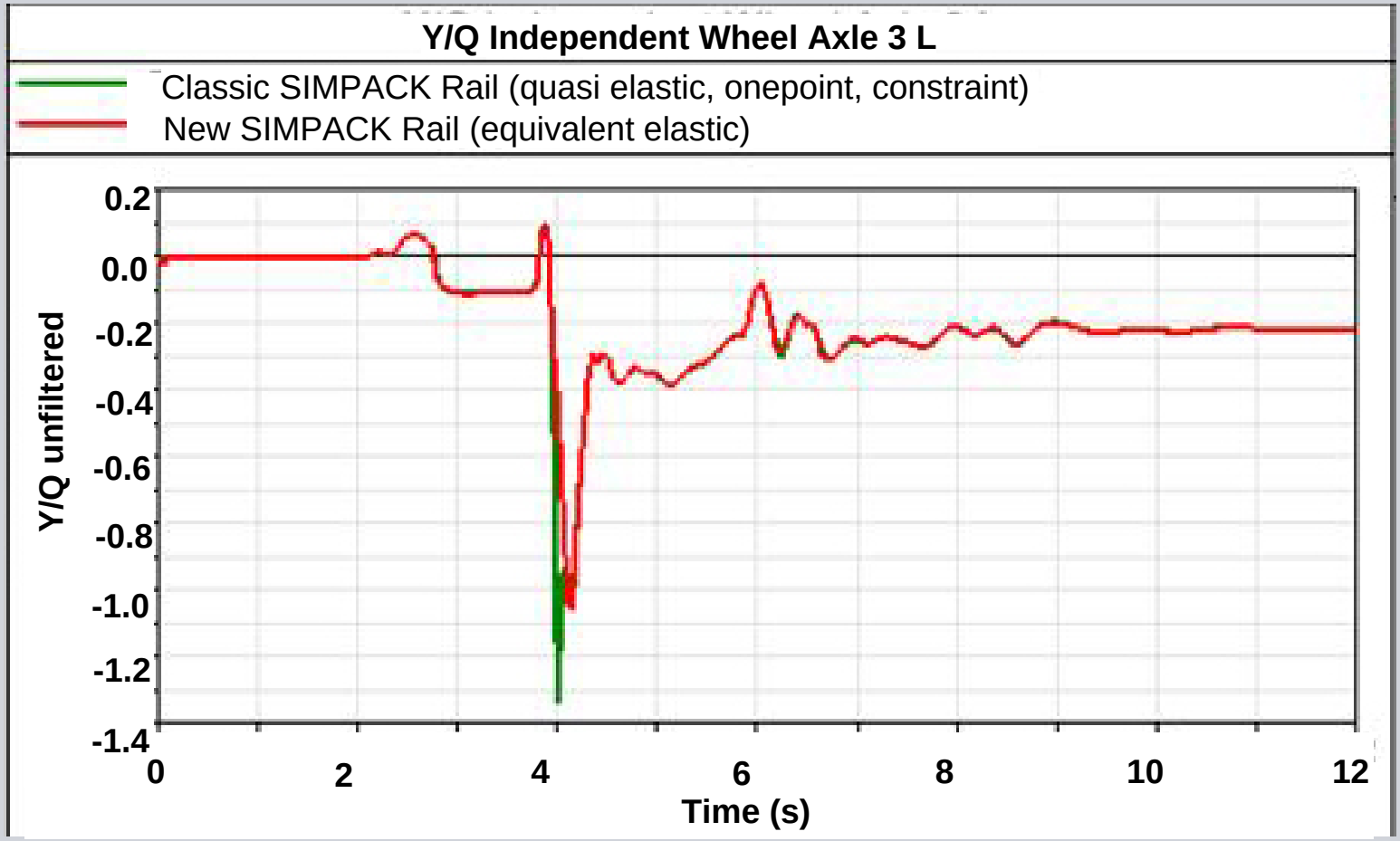
# Articulated train – large unbalanced lateral acceleration

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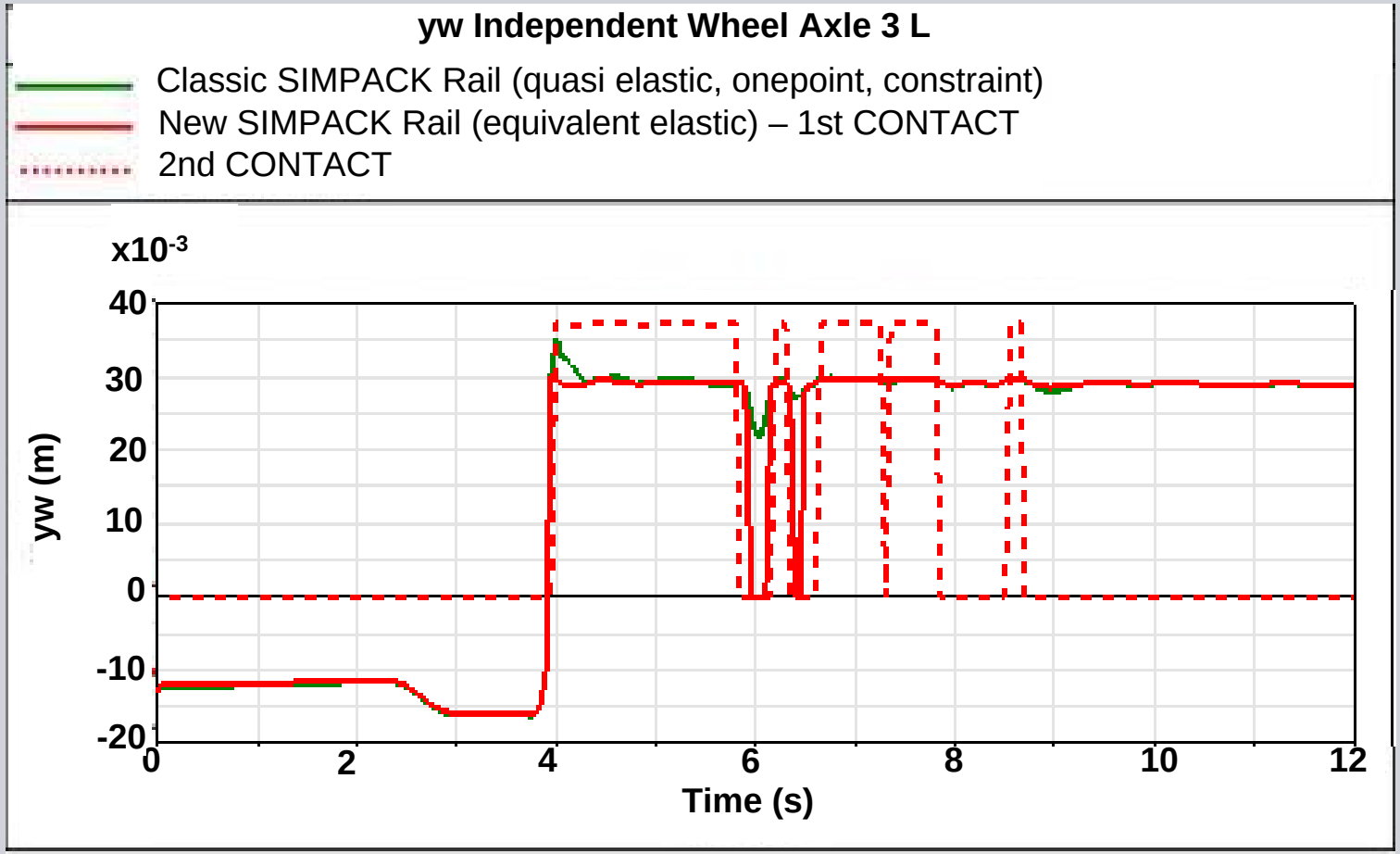


**Additional contact patches are found.**


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## Conclusions and Outlook

- Following a long history of software verification also the New SIMPACK Rail will be verified by INTEC and Siemens TS.

- Several verification procedures are used:
  - INTEC internal procedures
  - Collaboration INTEC / Siemens TS
  - Siemens TS internal procedures

- Results with equivalent elastic contact show good agreement so far.
  - A more realistic contact patch search for multipoint contact has been reached.

- Tests will be continued both at INTEC and Siemens TS.
- Fully non-elliptic contact is available but needs further effort.

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