Methods for Running Stability Prediction and their Sensitivity to Wheel/Rail Contact Geometry

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Contents

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Motivation

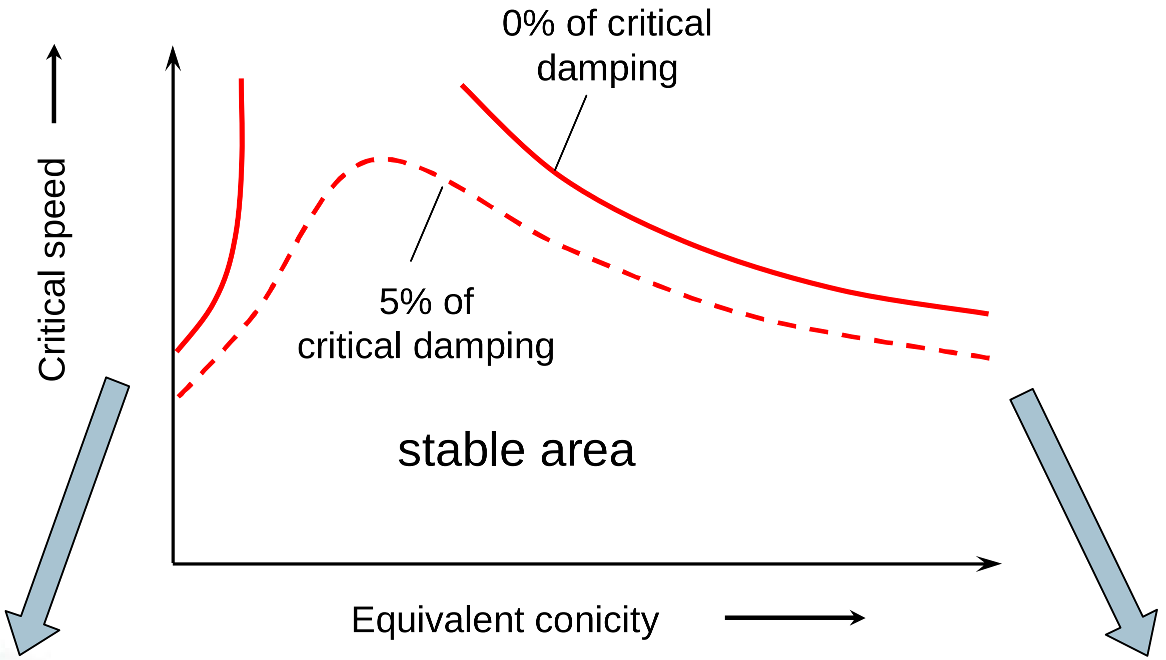
- **Typical task during the suspension design of railway vehicles:**
  - What is the maximum speed at which the vehicle will run stable for the specified equivalent conicity?

    or
  - Which suspension parameters are needed to run stable for the given speed and equivalent conicity?

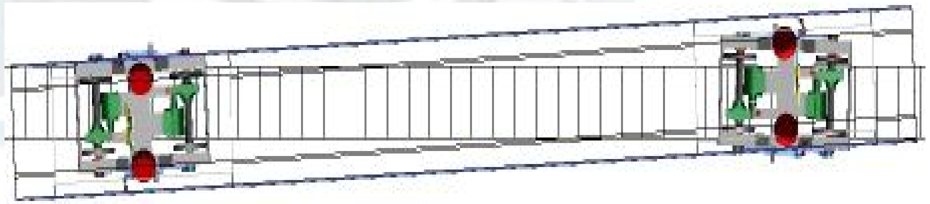
- **Questions to solve by the specialist:**
  - Which method and criteria should be used?

    and
  - How to model the specified equivalent conicity in the nonlinear simulations?

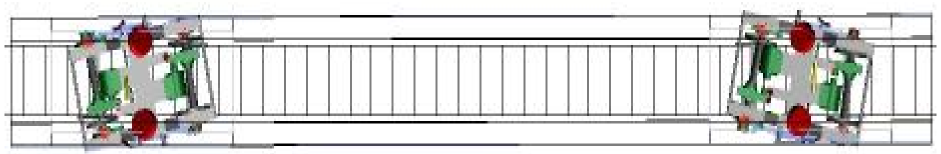
Bogie and Carbody Stability



Carbody hunting



Bogie hunting



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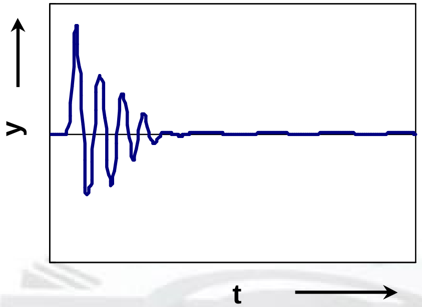
Definition of Stability Limit

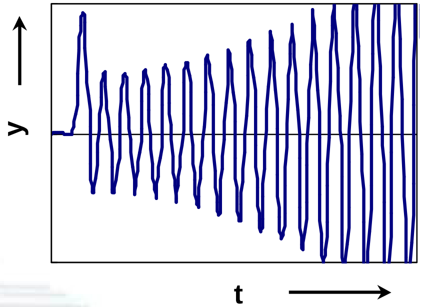
§ **Difference: Mechanics – Railway Standards**

Mechanics

stable

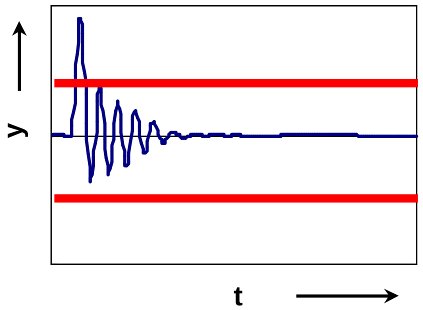


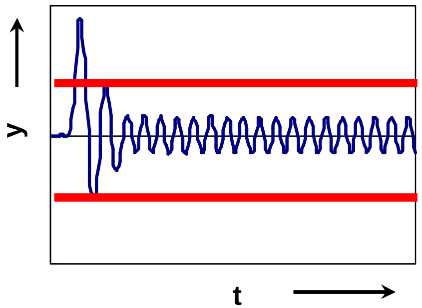
unstable



Railway Standards

stable





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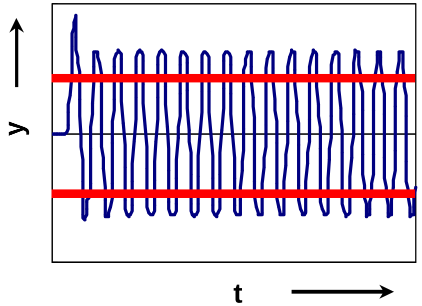
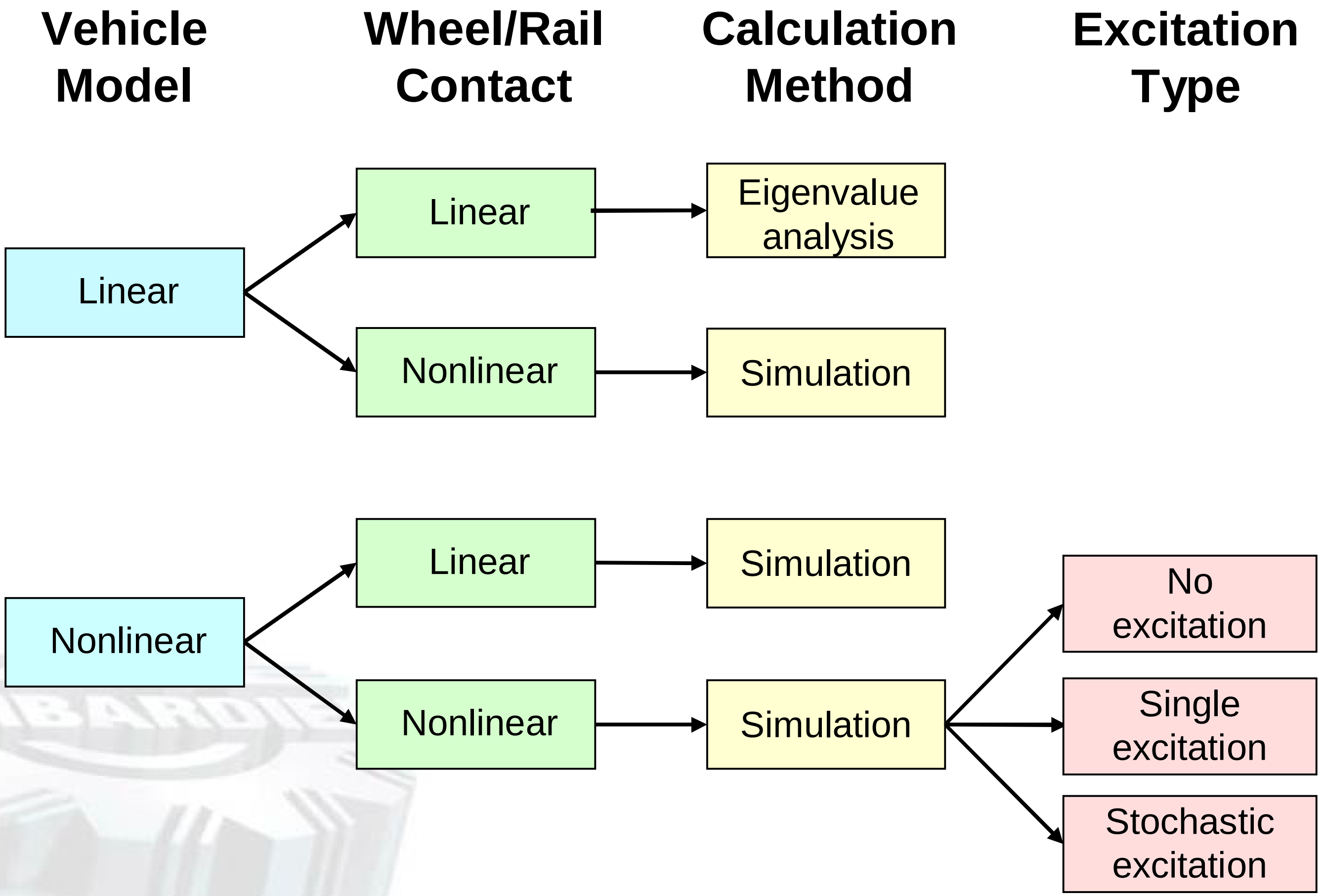
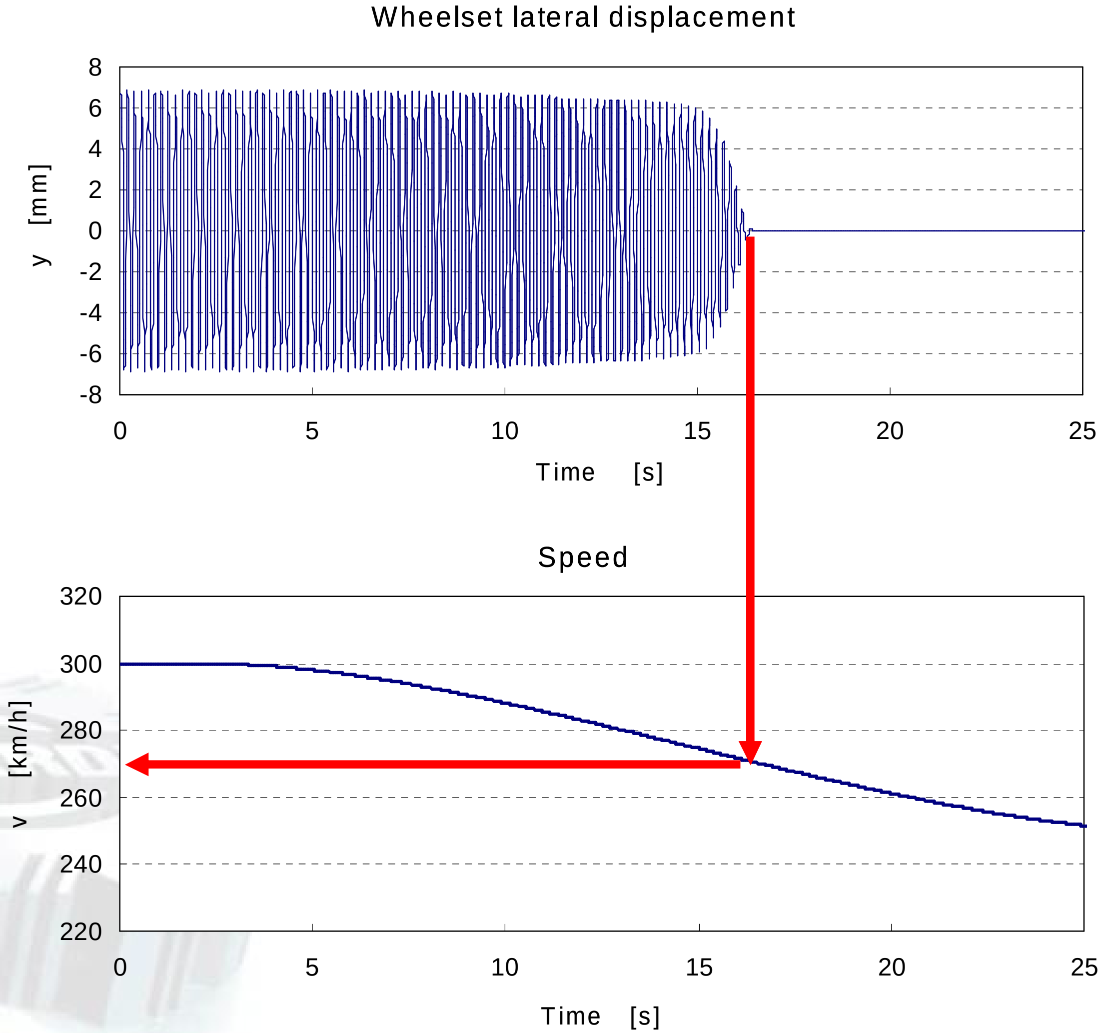


Classification of Methods for Stability Analysis



Simulation of Run with Decreasing Speed (No Excitation)



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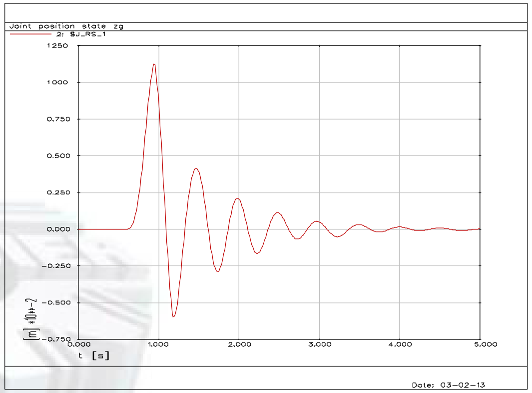
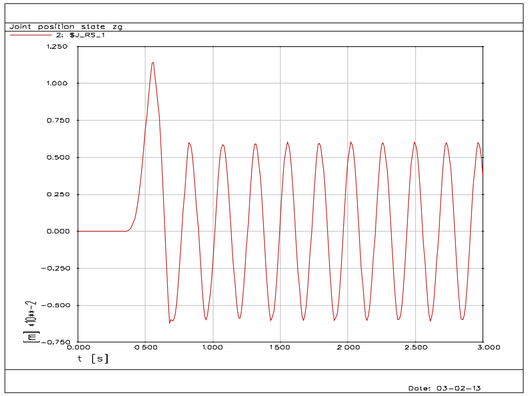
Excitation by a Single Lateral Irregularity

stable



unstable



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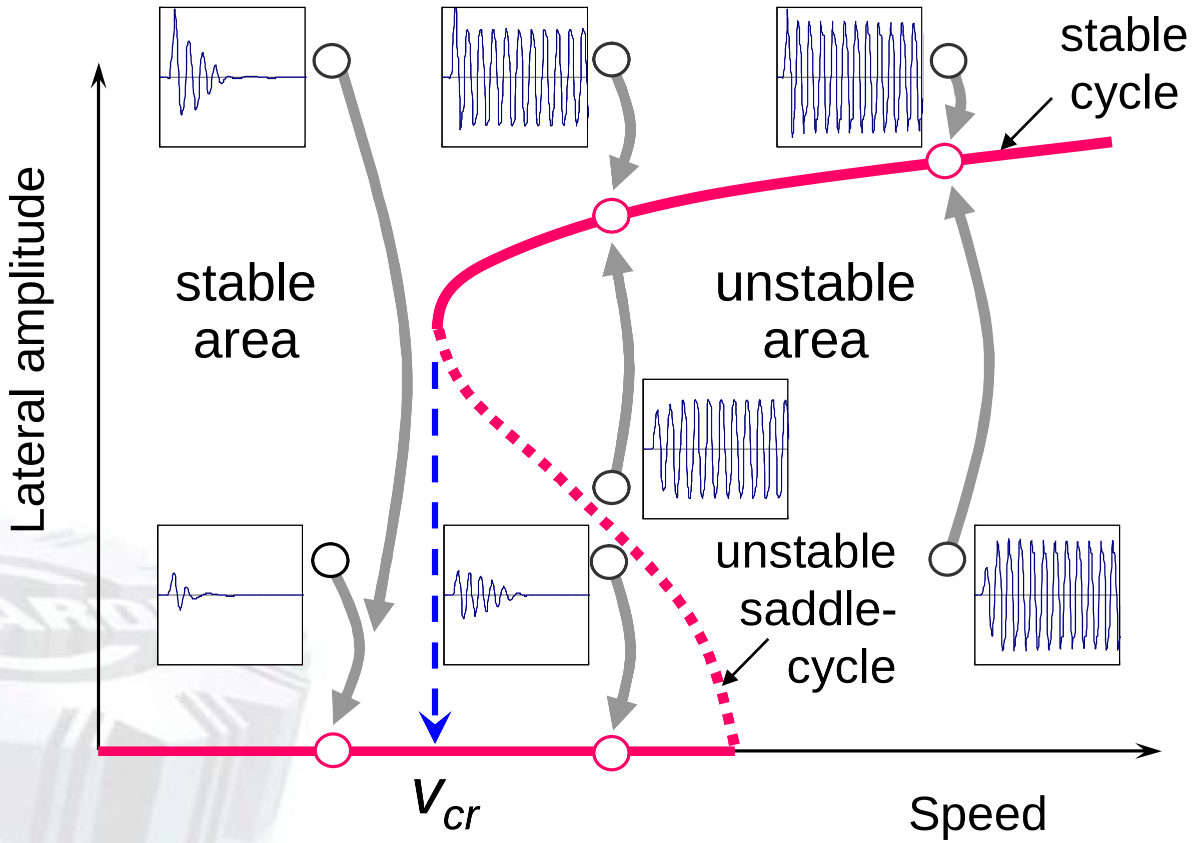
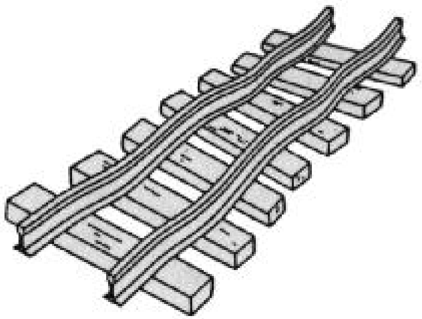
Bifurcation Diagram

- **Amplitude of the limit cycle as function of speed**

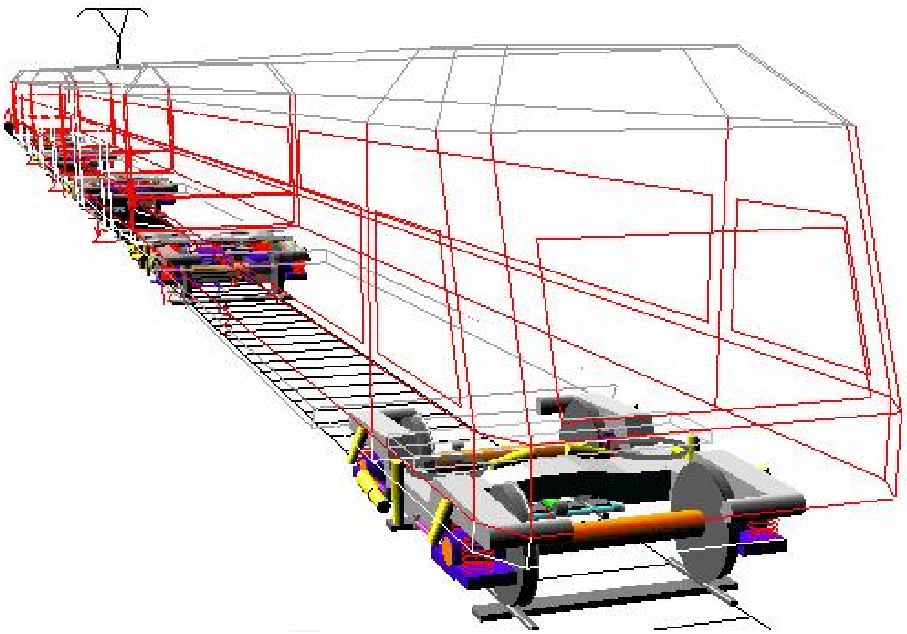


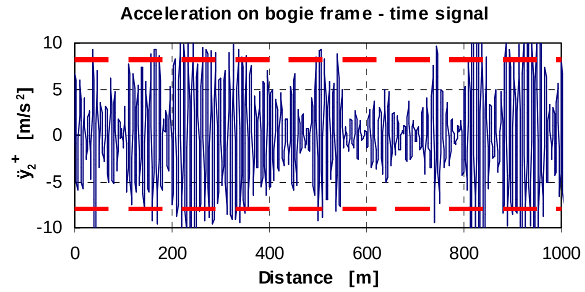
Simulation of Run on Measured Track Irregularity

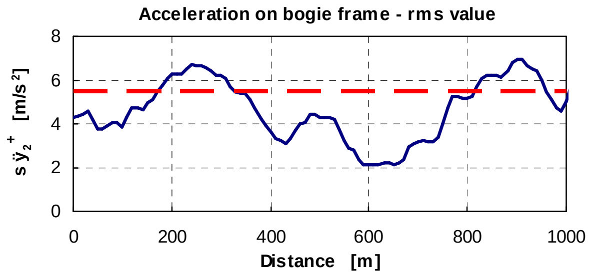
Track Irregularity → Simulation → Signal Analysis

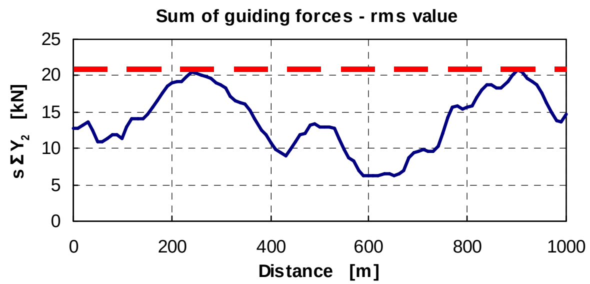


- Limit values according to standards (UIC 518, prEN 14 363):
- Acceleration, rms value
- Sum of guiding forces, rms value



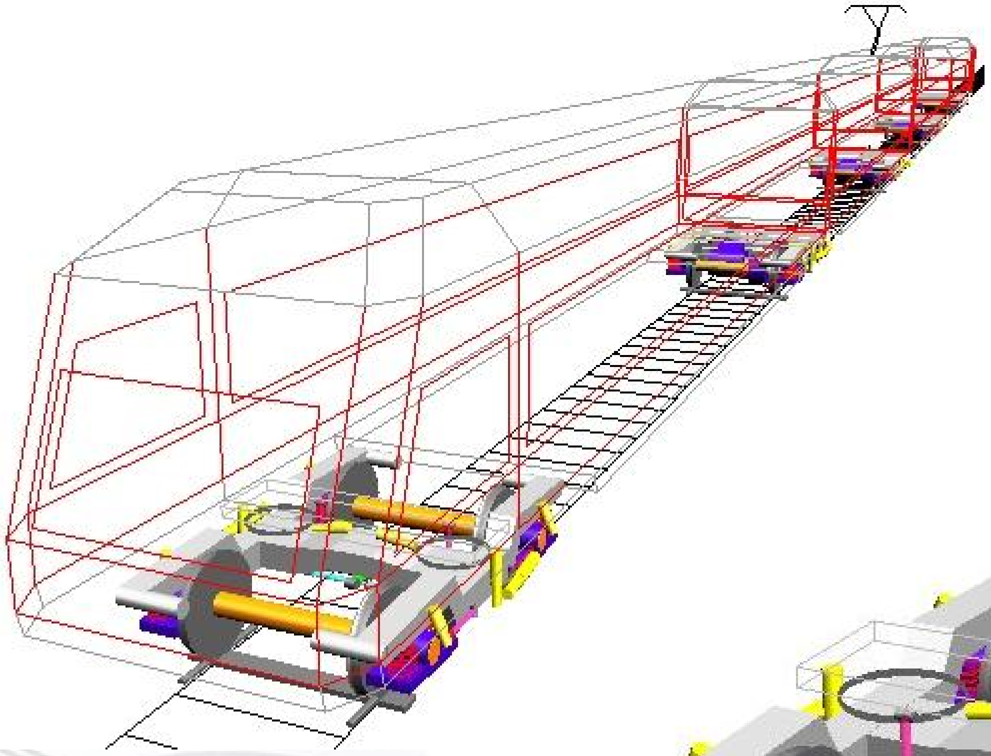


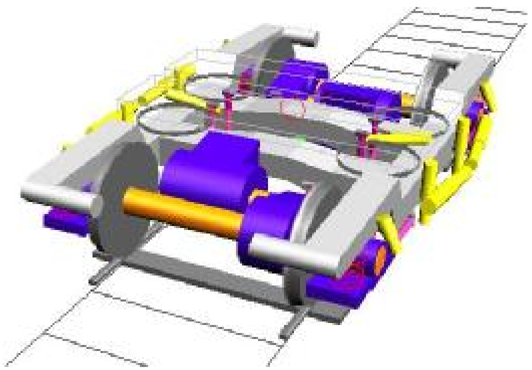


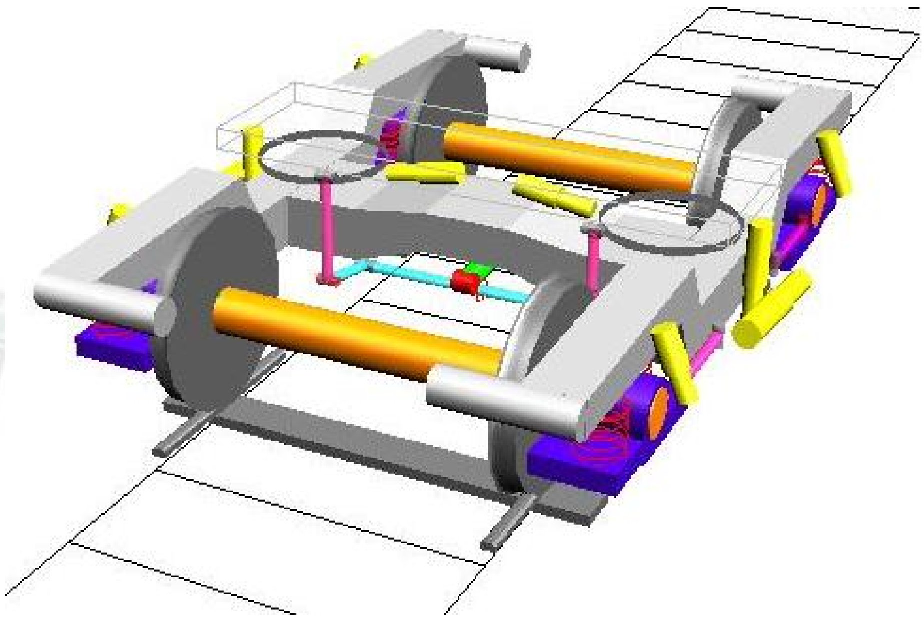


Vehicle Model

- **A four-car articulated vehicle modelled in Simpack**
- **Wheel/rail friction coefficient 0.4 (dry)**

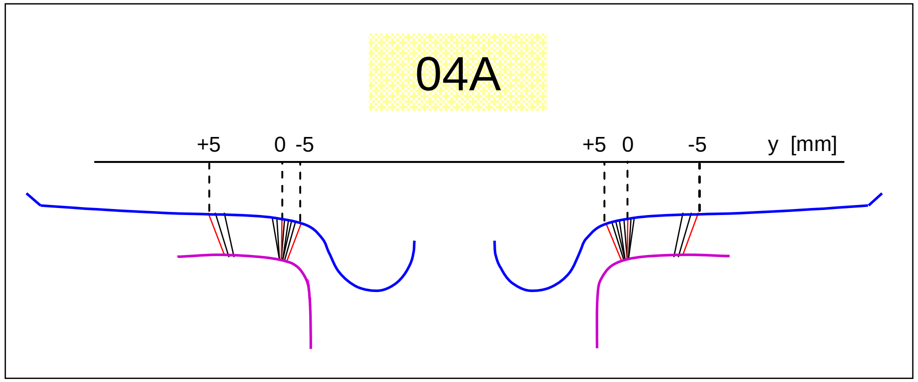


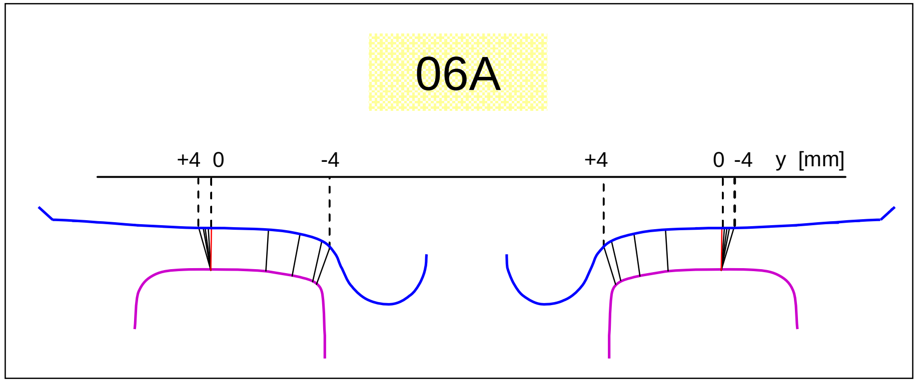


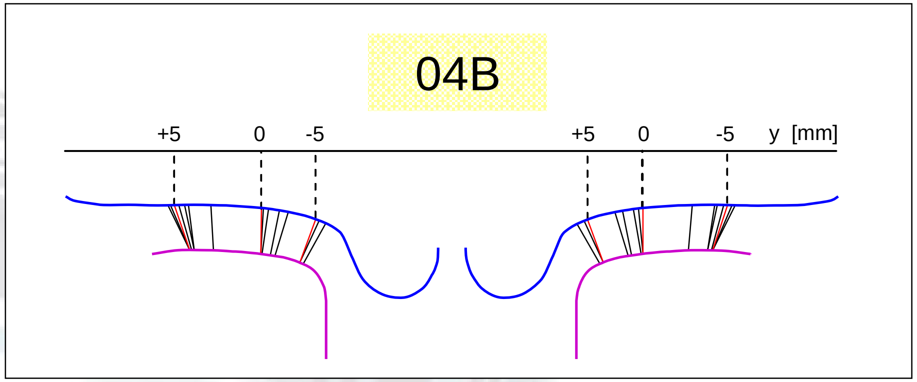


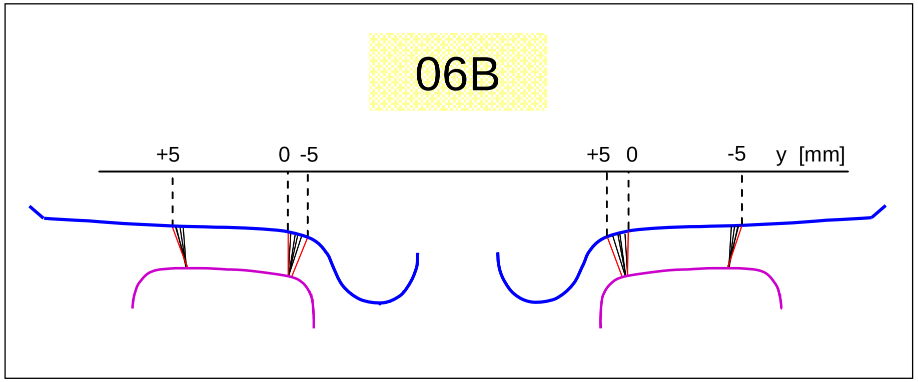
Examples of Contact Geometry Wheelset/Track

- Equivalent conicity: Specified for wheelset lateral amplitude of 3 mm
- Four examples of wheel/rail contact geometry









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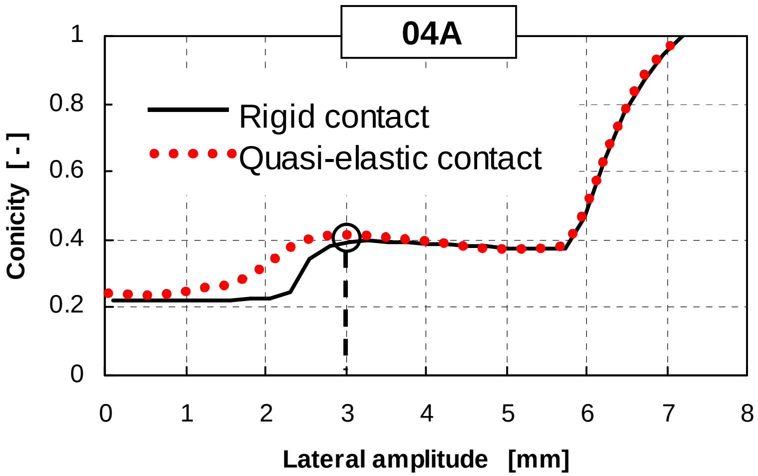
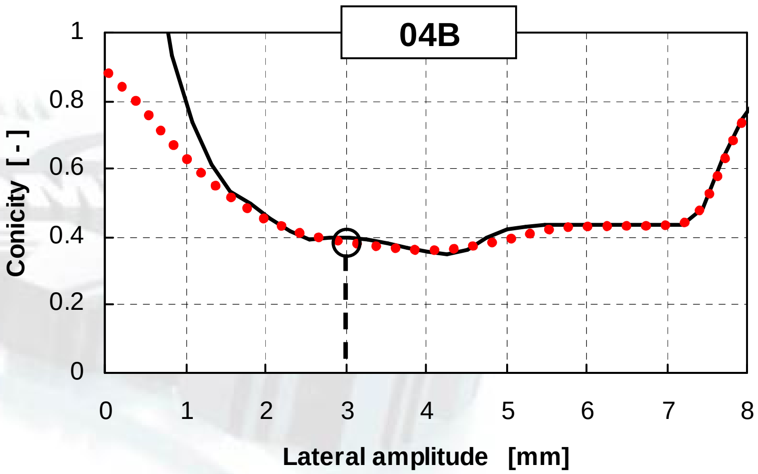
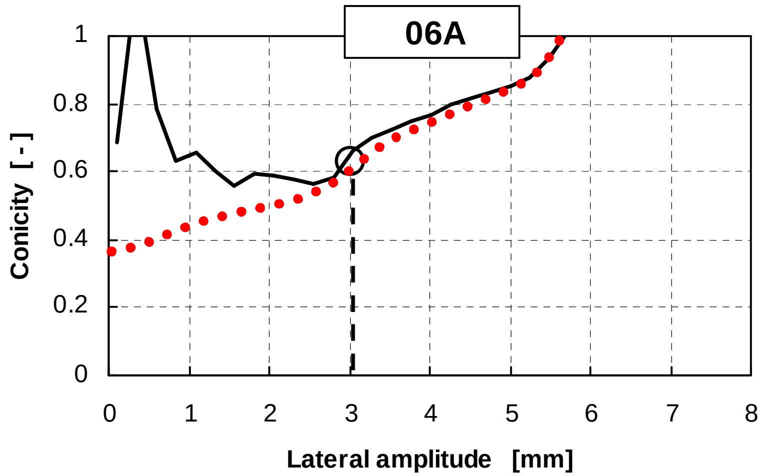
Equivalent Conicity Function

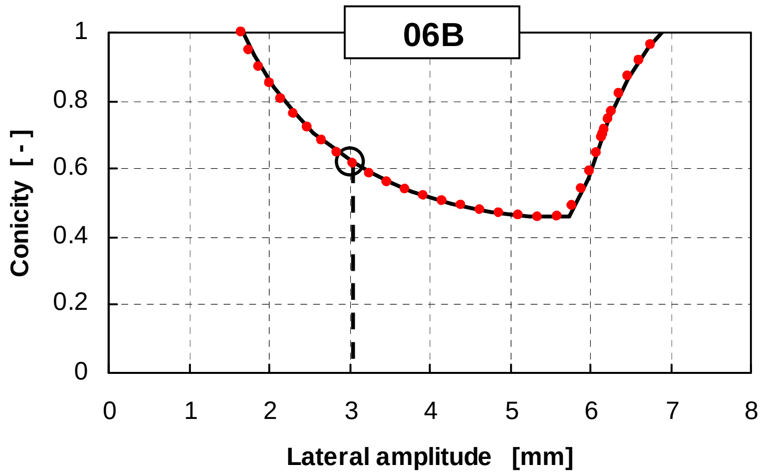
Conicity 0.4



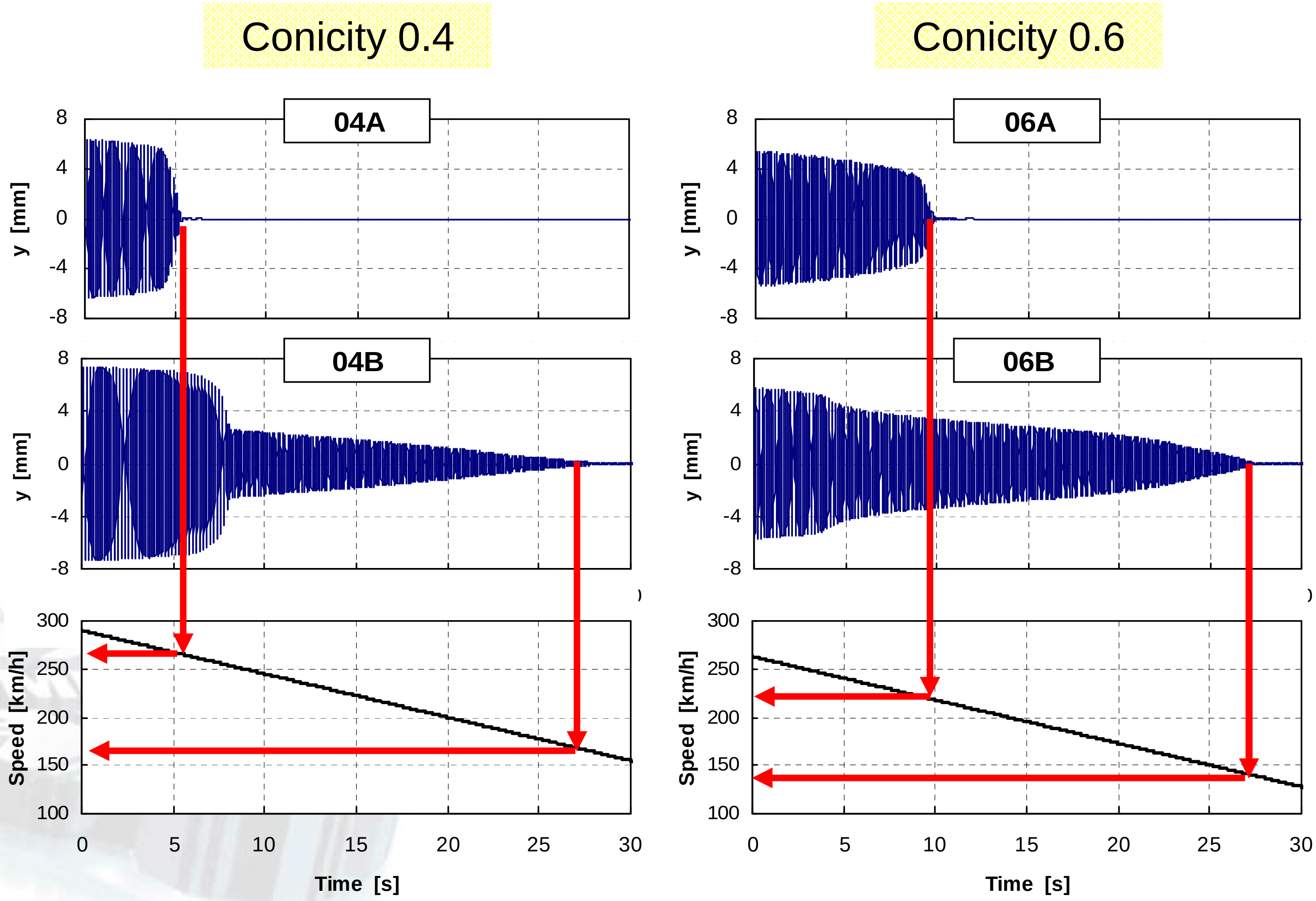


Conicity 0.6





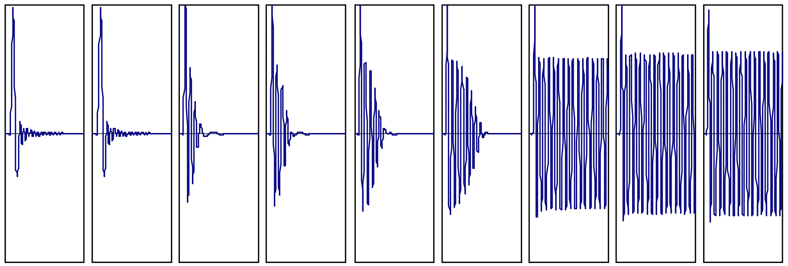
Simulations of Run with Decreasing Speed



Method with Single Excitation

Conicity 0.4

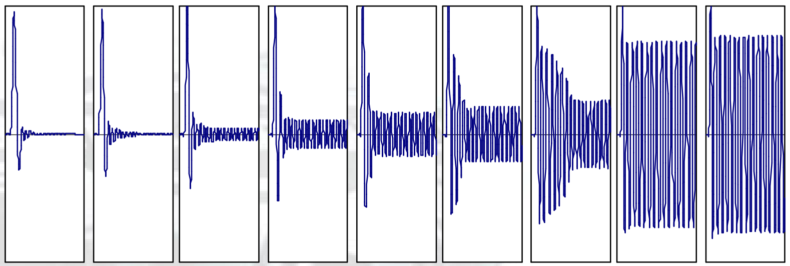
04A



220 230 240 250 260 270 280 290 300

Speed [km/h]

04B

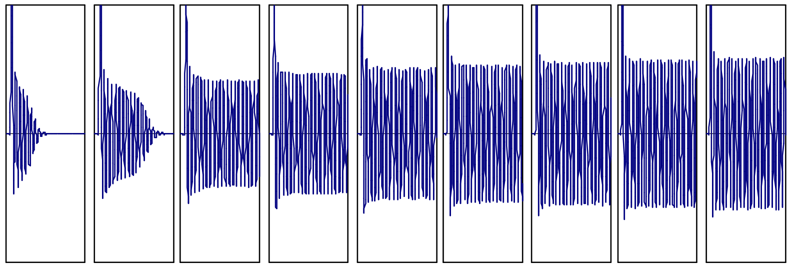


140 160 180 200 220 240 260 280 300

Speed [km/h]

Conicity 0.6

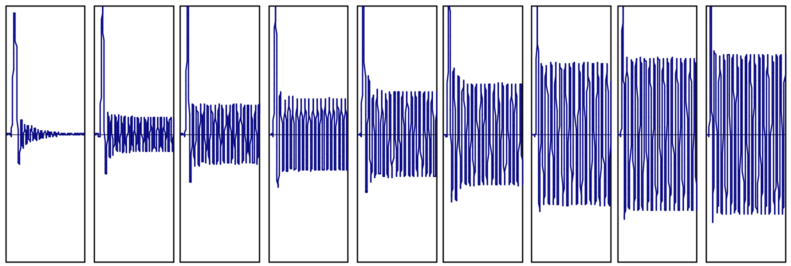
06A



220 230 240 250 260 270 280 290 300

Speed [km/h]

06B



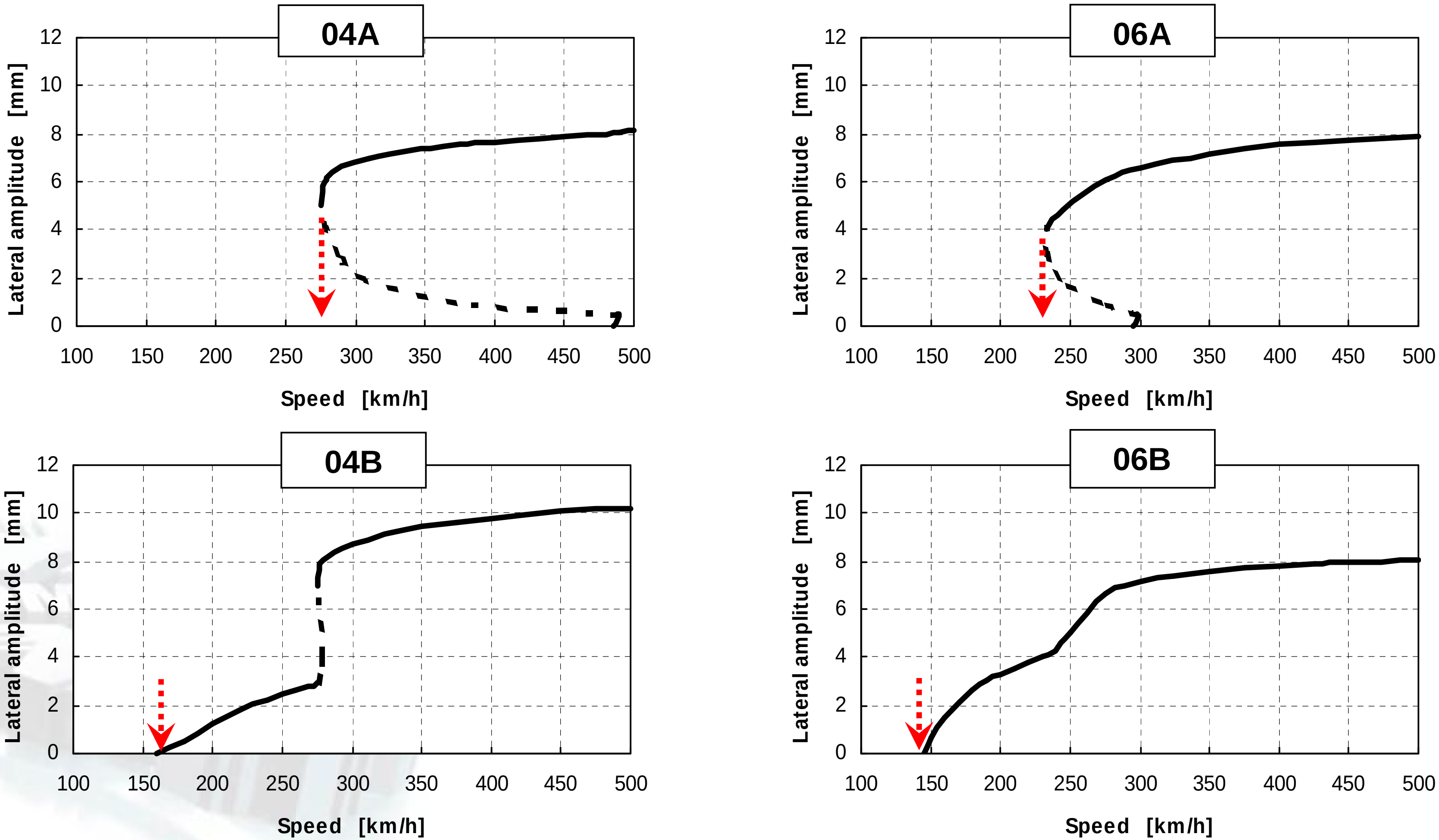
140 160 180 200 220 240 260 280 300

Speed [km/h]

Bifurcation Diagrams

Conicity 0.4

Conicity 0.6



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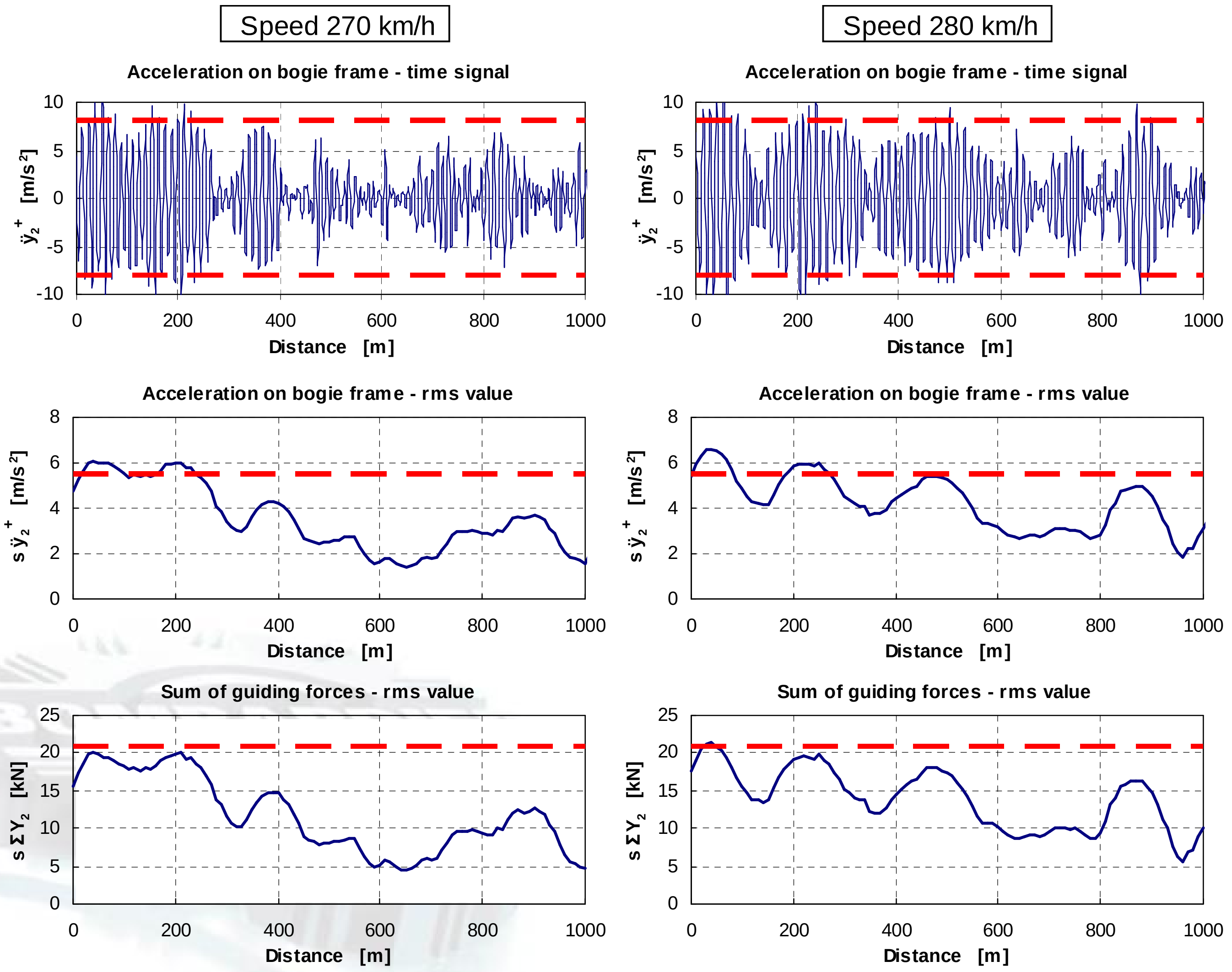
Simulations of Run on Measured Track Irregularities



- **Lateral acceleration, time signal**
- **Lateral acceleration, rms value (UIC 518)**
- **Sum of guiding forces, rms value (UIC 518)**

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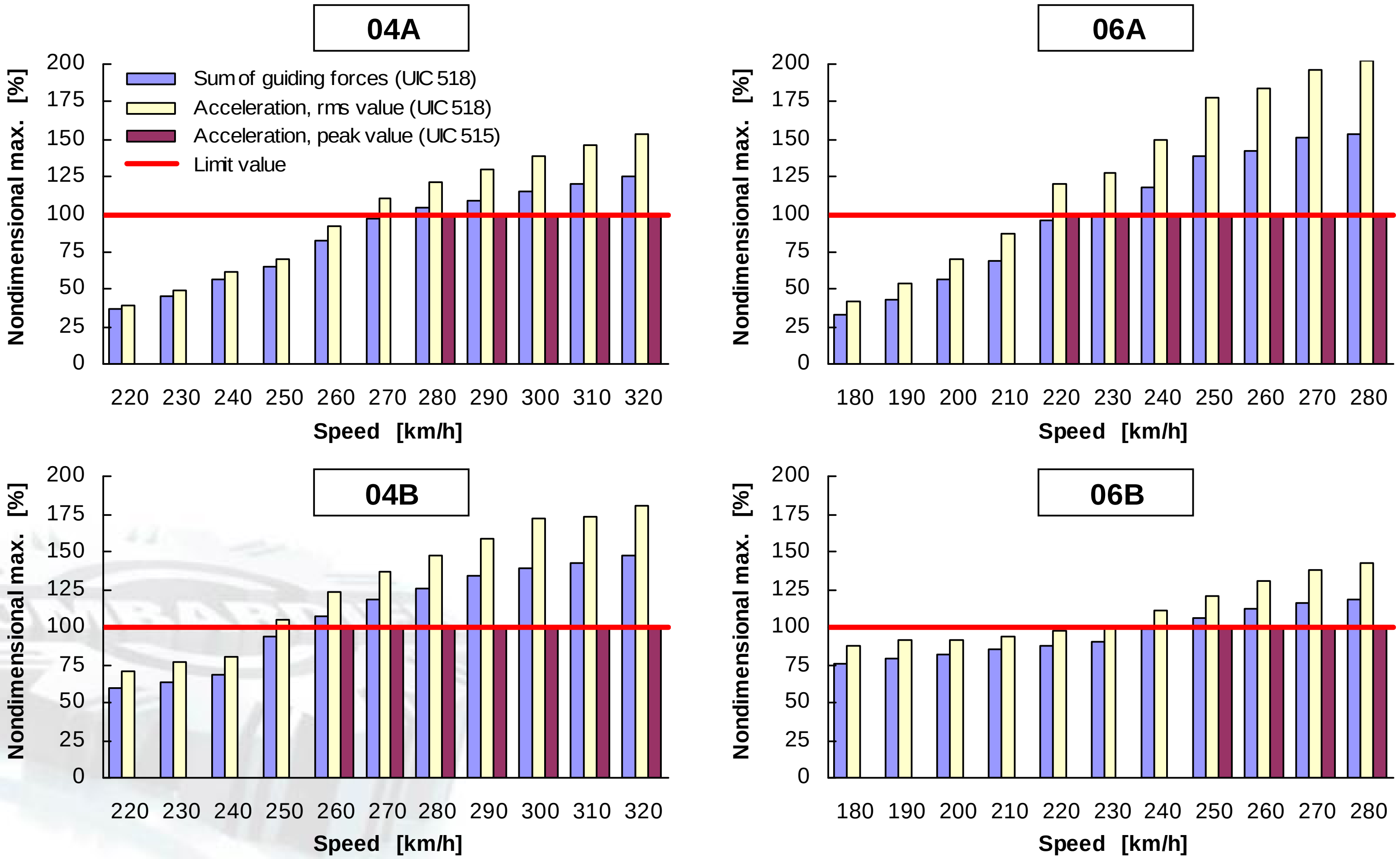
Results of Simulations on Track Irregularities

Conicity 0.4 | **Conicity 0.6**



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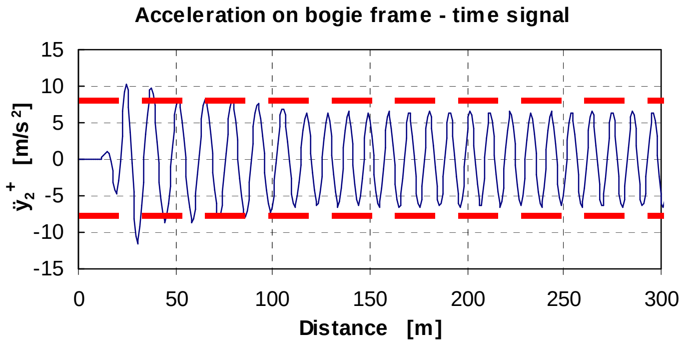
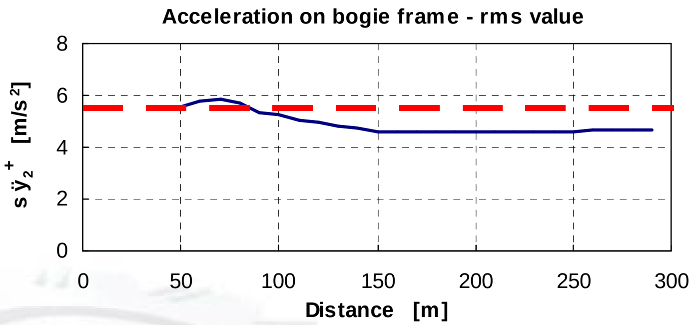
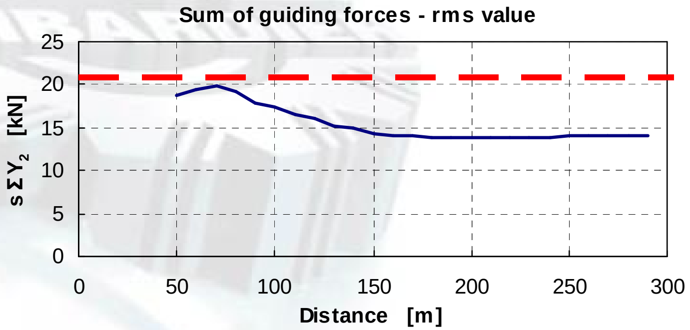
Dynamic Behaviour after a Single Excitation

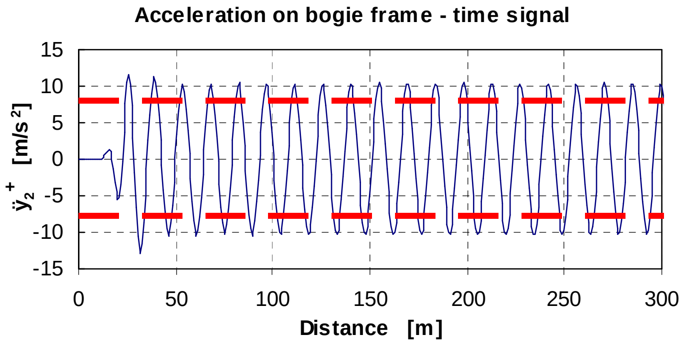
Speed 260 km/h

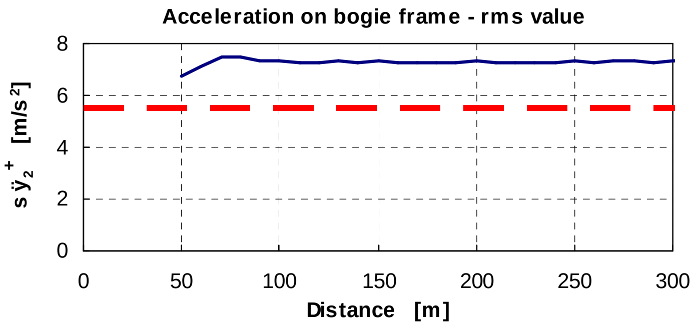


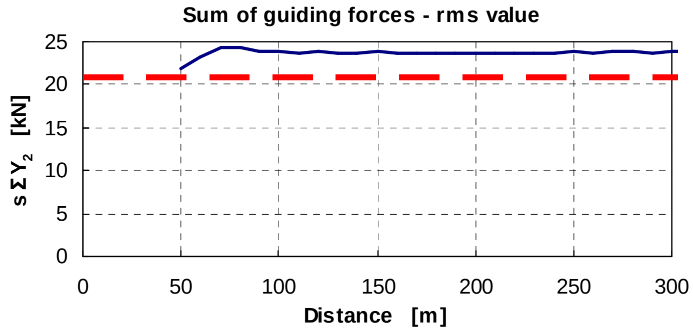




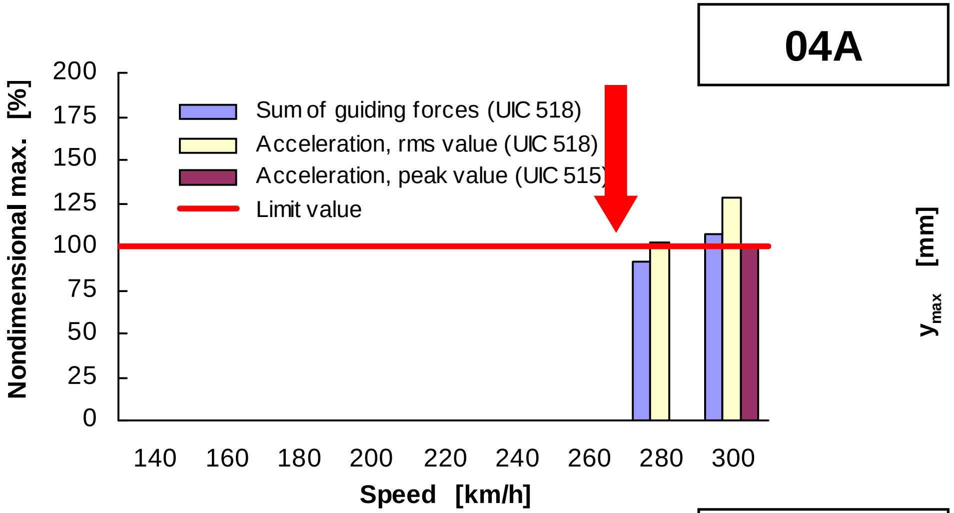
Speed 280 km/h

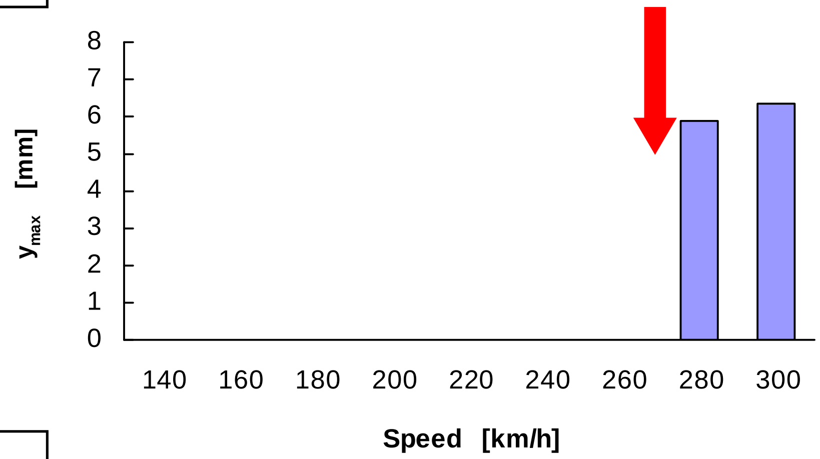


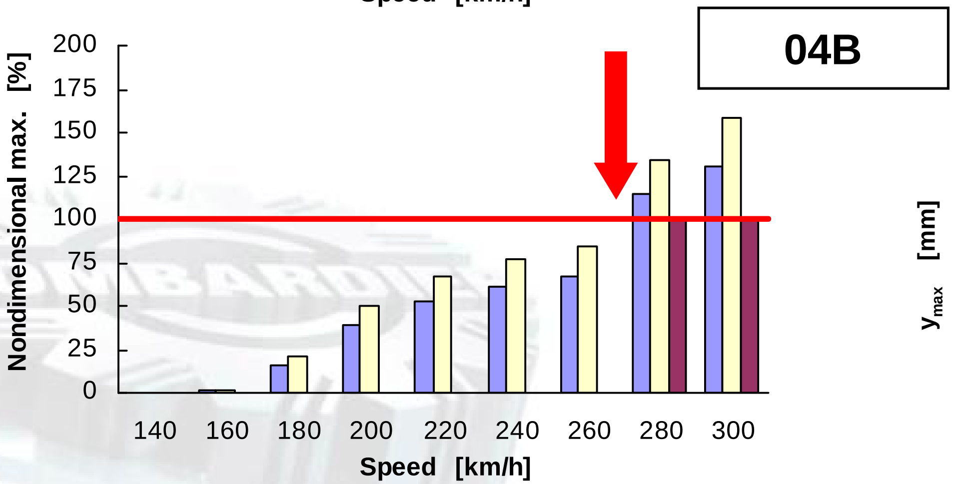


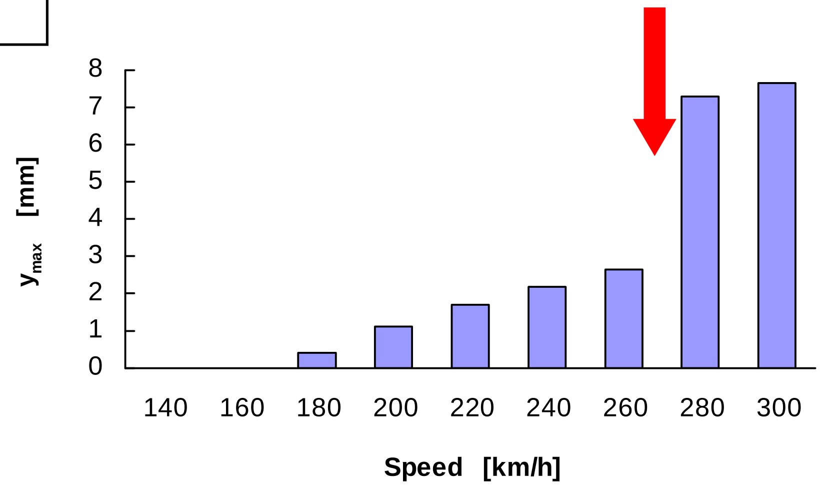


Stability Assessment of Behaviour after a Single Excitation









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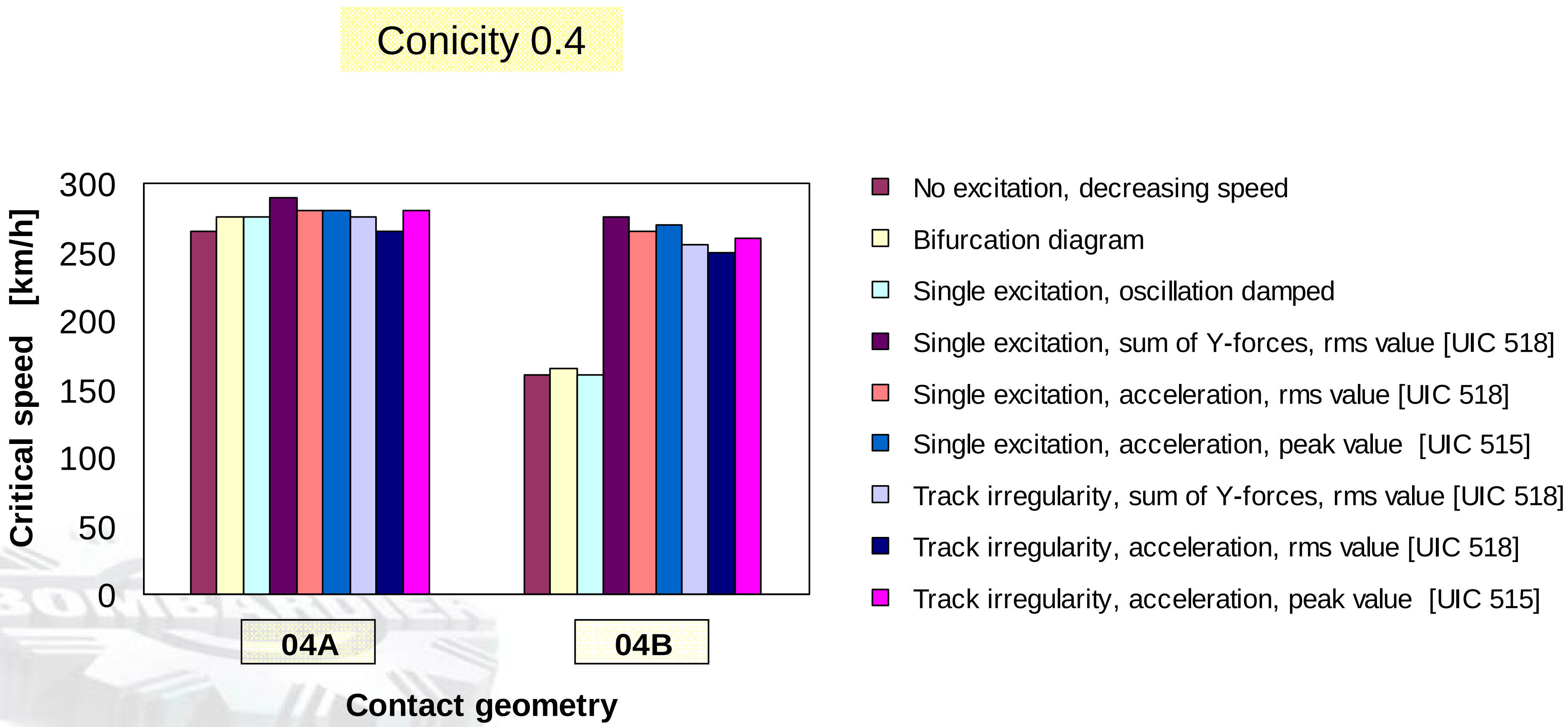
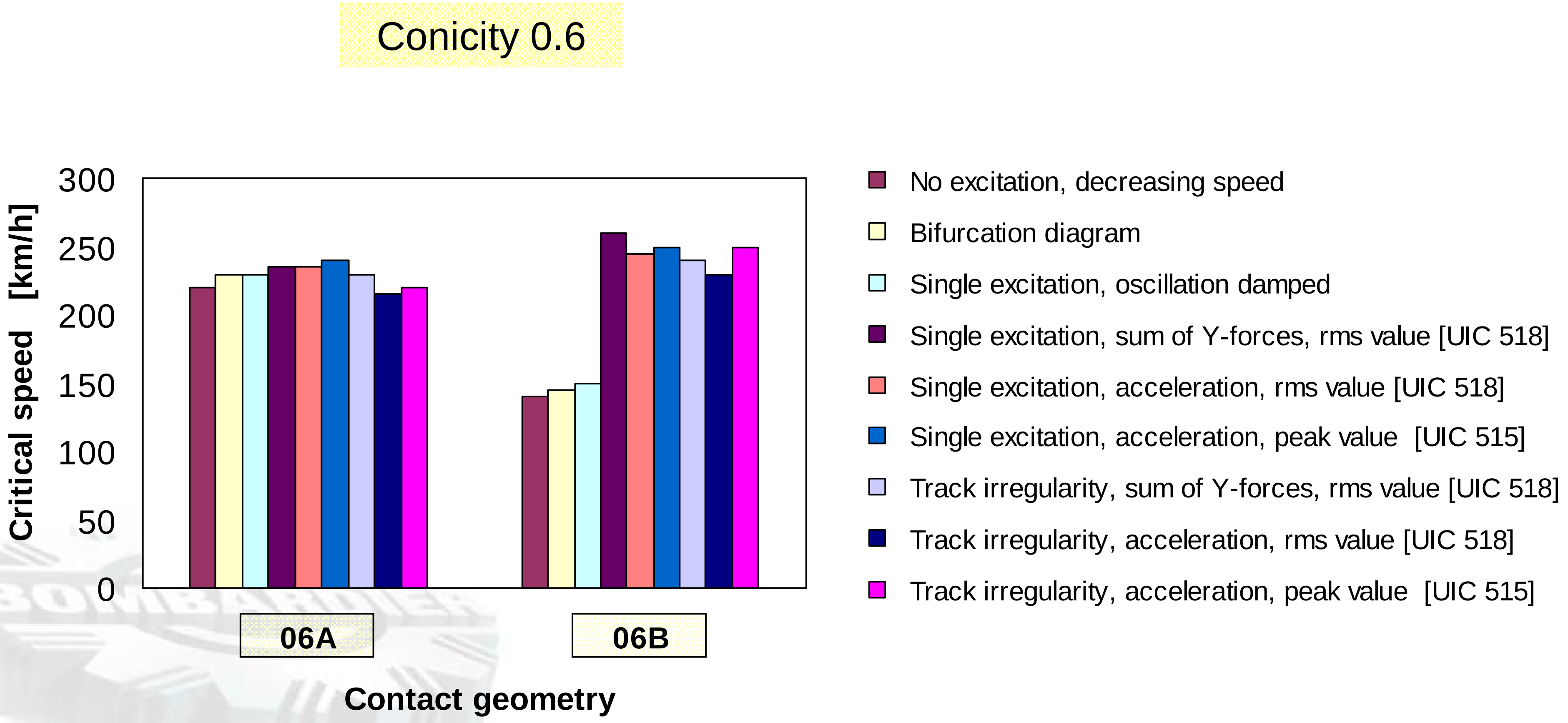
Comparison of Resultant Critical Speeds



Comparison of Resultant Critical Speeds



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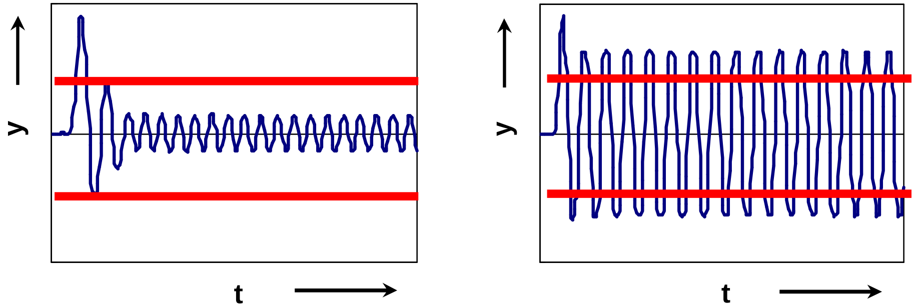
Conclusions (1): Nonlinear Method for Stability Analysis

- Difference in definition of stability between Mechanics and Railway Engineering
- The methods presented are comparable if no limit cycles with small amplitude occur
- For a specified conicity, differences between the results occur dependent on the method, limit value and the contact geometry
- If small limit cycles occur stability limits from the railway standards should be used to judge the results



Conclusions (2): Specification of Wheel/Rail Contact

- Specification of the shape of wheel profile, rail profile, rail inclination and gauge
- Separate specification of the maximum wheelset related equivalent conicity and the maximum track related equivalent conicity
- Only the maximum equivalent conicity specified: Recommended to use wheel/rail contact geometry with increasing or constant conicity function to avoid small limit cycles