

Simulation of Railway Wheel Profile Evolution due to Wear



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BOMBARDIER

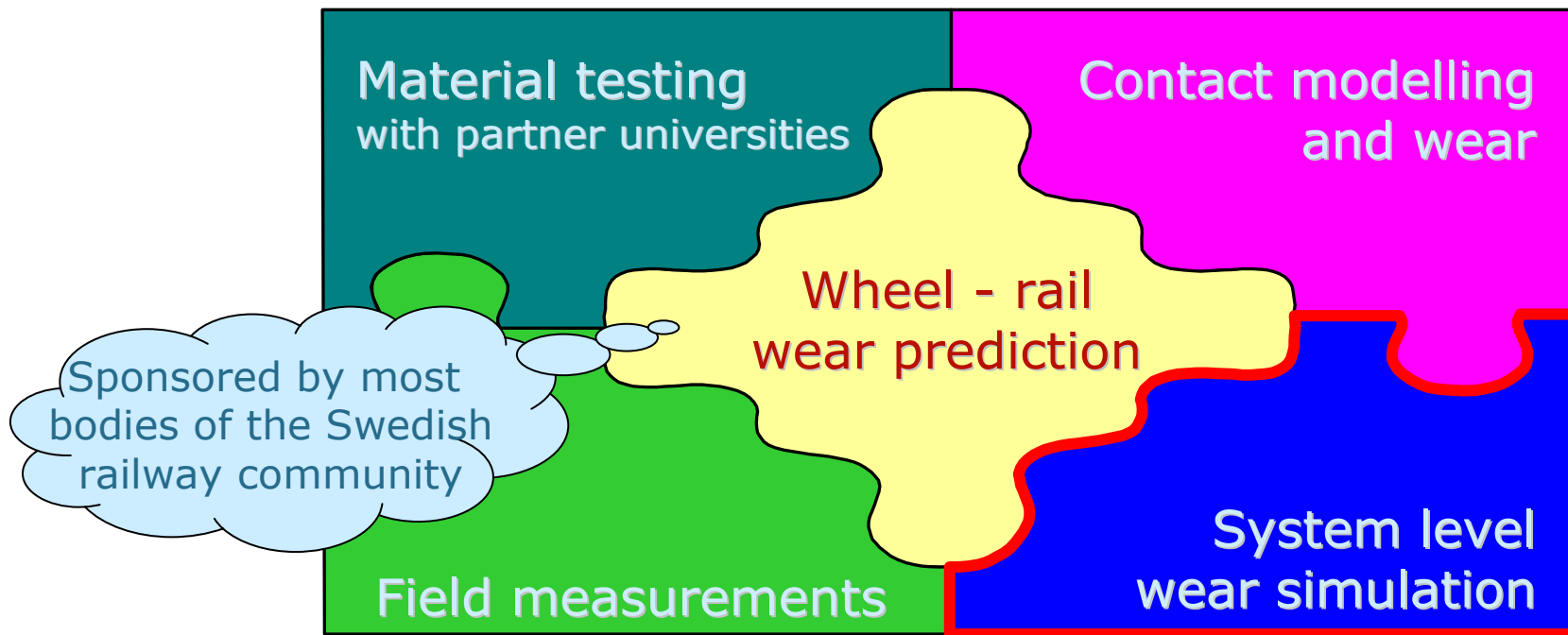
Outline

- **Scientific foundation**
 - Basic methodology
 - Method validation
 - Further applications
- **Simpack implementation structure**
 - Wear model interface
 - New result element
 - Parameter variation functionality
- **Test examples**
 - Contact modelling issues
 - Elementary cases
 - Reference case



Wheel/rail contact research at Royal Institute of Technology (KTH), Stockholm

- Research programme initiated 1995
- Divisions of Rail Vehicles and Machine Elements



System simulation objective

- **Project goals**

- Quantitative prediction of wheel and rail profile evolution to a resolution sufficient for dynamic simulations
- Proposed system improvements for wear reduction

- **Project means**

- Systematic selection of simulations adequately representing the actual operation
- Numerical simulation of the vehicle/track interaction by MBS formalism
- Relevant contact and material loss models
- Validation through full scale measurements

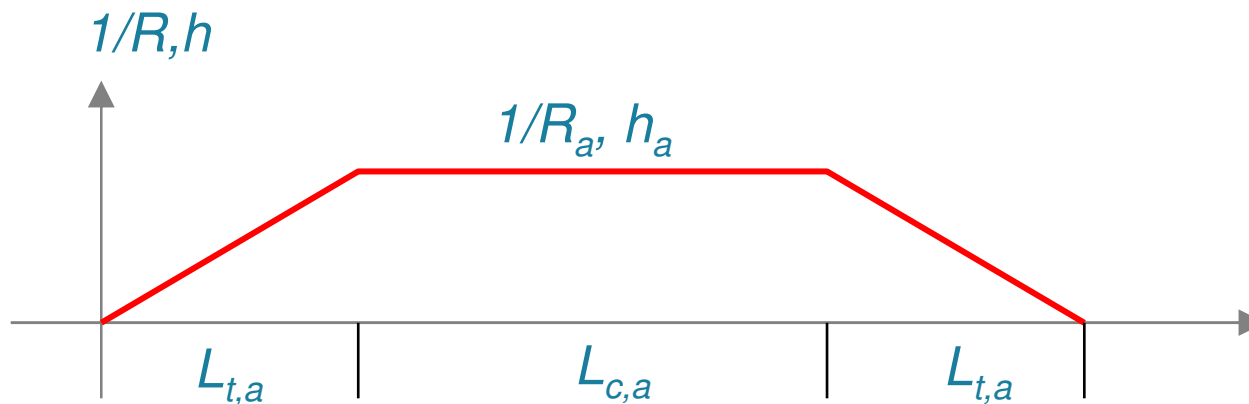
Wear simulation cornerstones

- **Simulation set:** A discretisation of the network to be considered, represented by an adequate selection of simulation cases
- **Dynamic model:** MBS model of the vehicle to be investigated
- **Wear model:** Relation between contact quantities (stresses, slip) and material removal
- **Profile updating:** Influence of material removal on the profile geometry considering actual contact positions

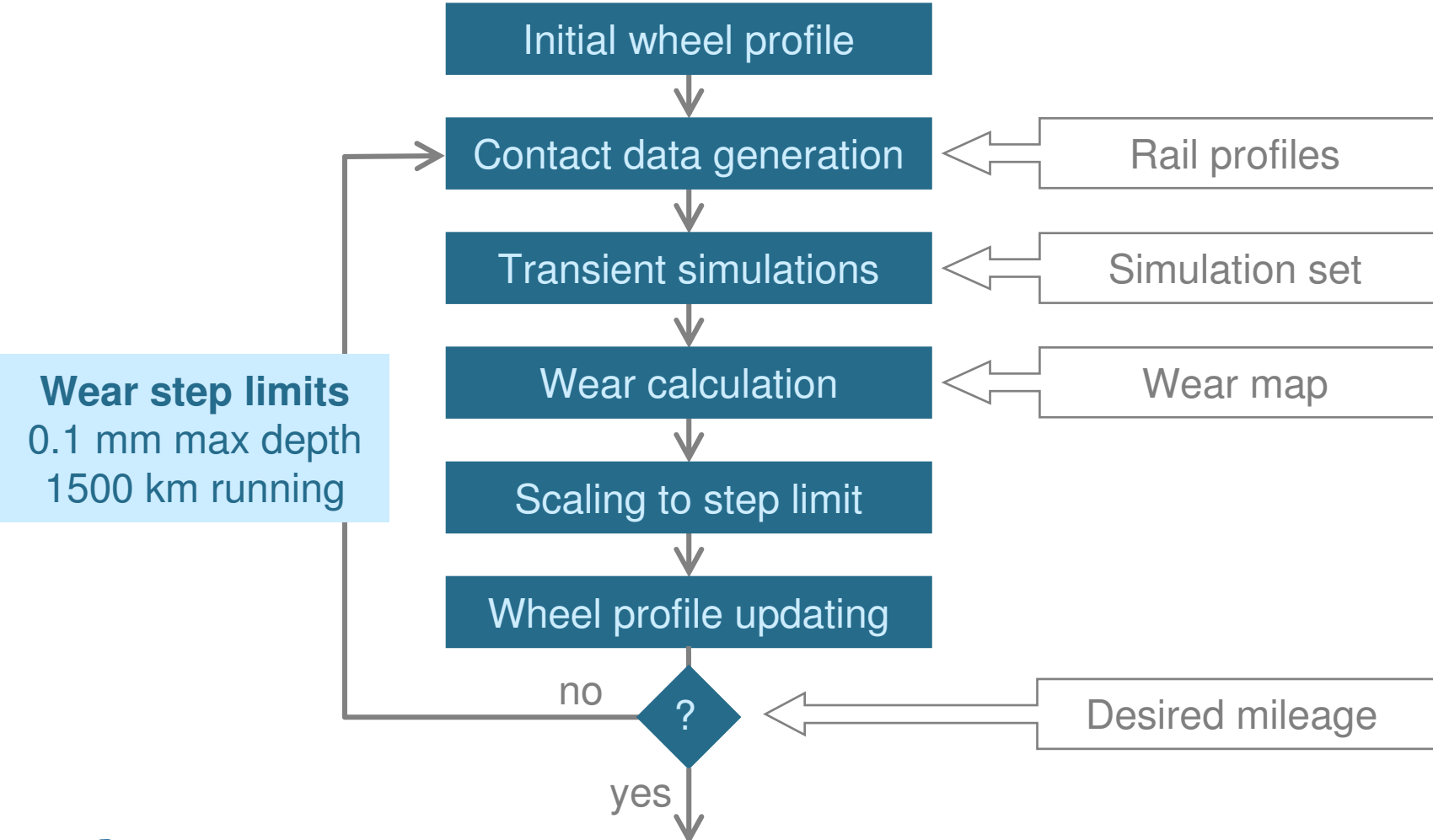
Wear simulation approach

■ Simulation set design

- Main discretisation parameter is the radius in the circular part of each curve
- For each defined curve radius interval a type-curve is calculated
- The wear distribution is weighted by the total curve length in the interval
- Other parameters are speed, friction, rail profiles, track alignment

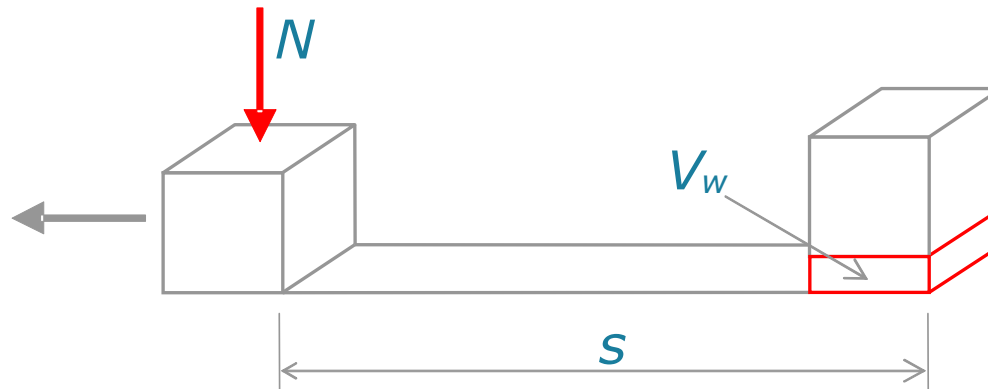


Wear simulation approach



Wear simulation approach

- Wear model - Archard's wear equation



$$V_w = k \cdot \frac{N \cdot s}{H}$$

Locally applied:

$$\Delta z = k \cdot \frac{p_z \cdot \Delta s}{H}$$

V_w = volume of wear [m³]

s = sliding distance [m]

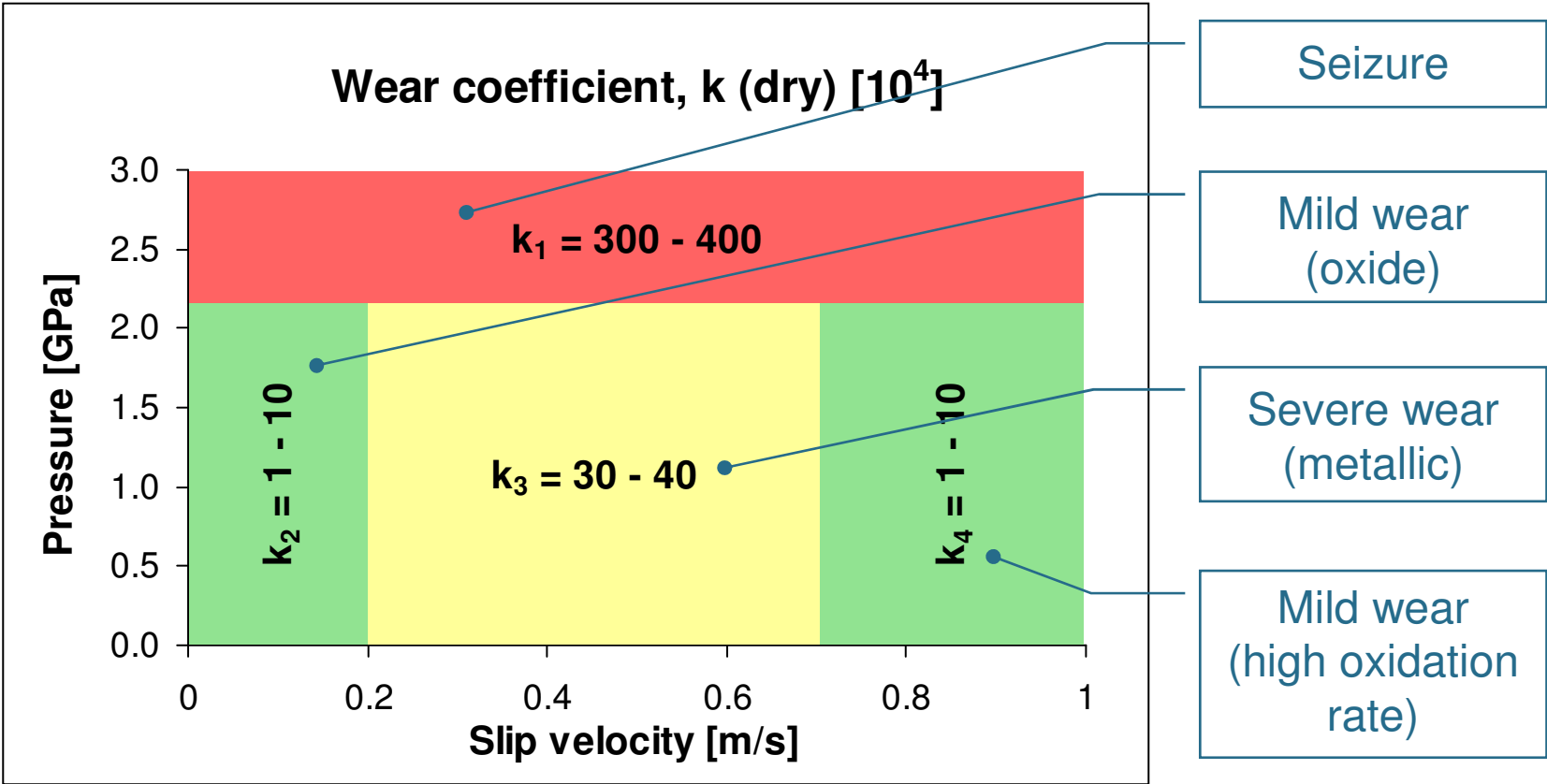
N = normal force [N]

H = hardness [Pa]

k = wear coefficient [-]

Wear simulation approach

- Wear model – Map of wear coefficients

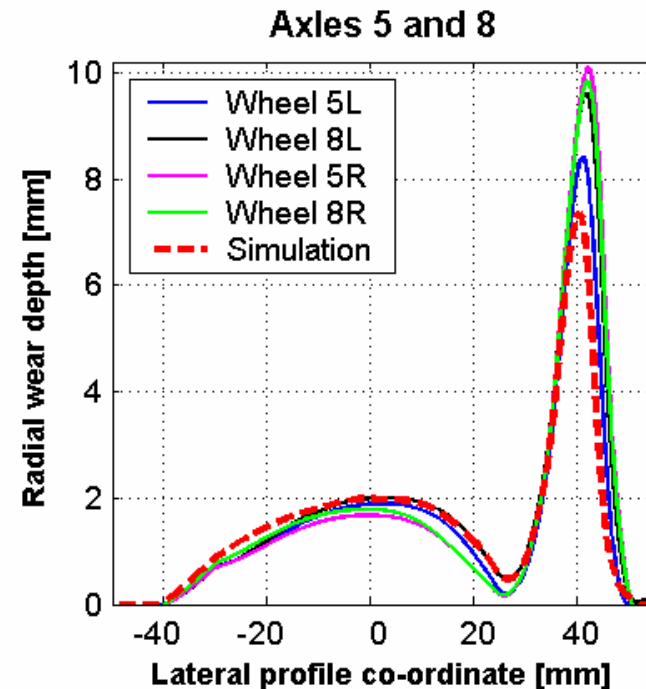
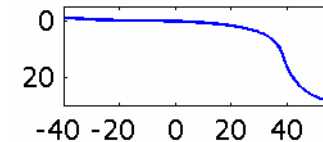


KTH wear simulation validation

Reference case Stockholm commuter

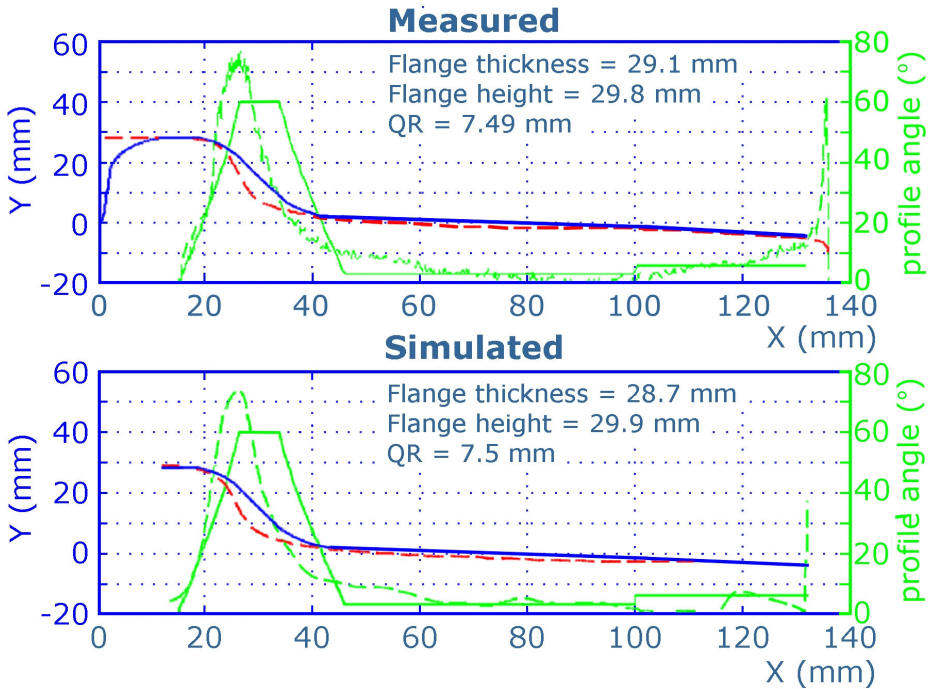
Radial wheel wear comparison

- 200 km network with curve radii 300 – 2000 m
- Simulated braking and elastic surface deformation
- Running distance 200 000 km



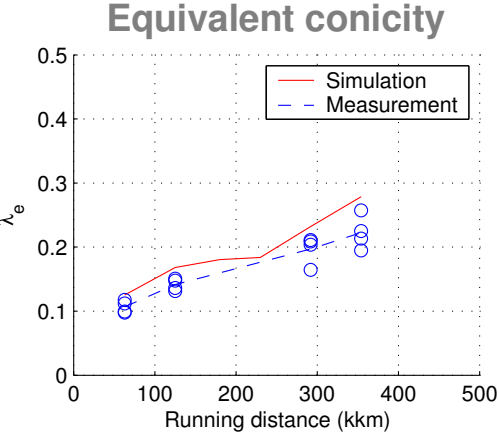
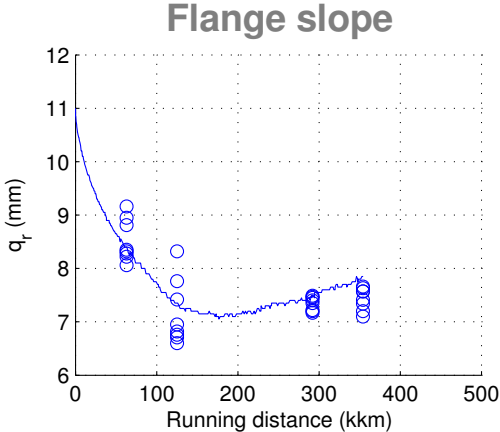
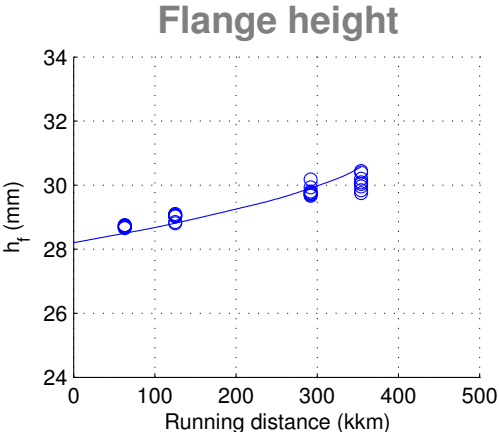
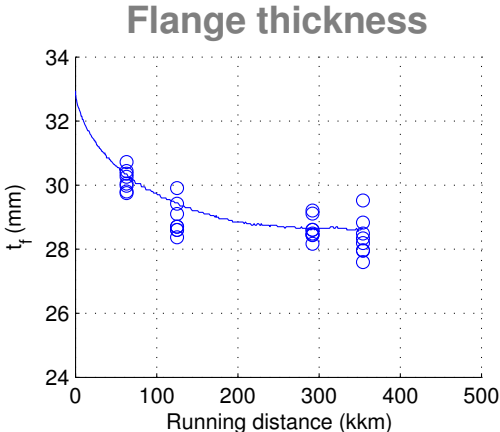
Further application by KTH/Bombardier Swedish tilting train X2000

- **Wheel profile comparison**
 - Running distance 292 000 km



Further application by KTH/Bombardier Swedish tilting train X2000

- Scalar wear measures



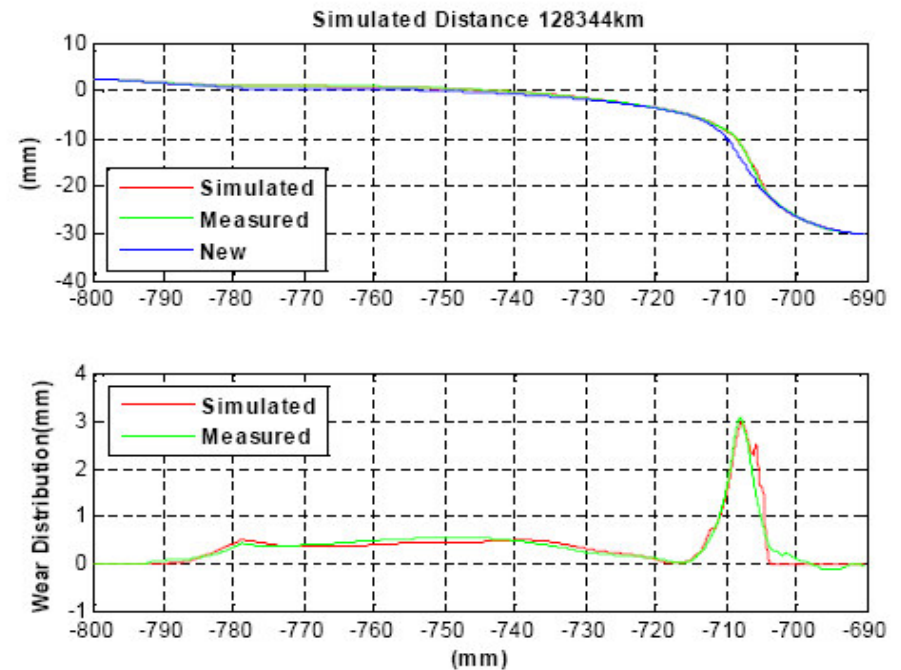
— Simulation
○ Measurement



UK application by Manchester Metropolitan University

Three different vehicles

- **Investigation of the anti RCF profile WRISA2**
 - Shape evolution due to wear
 - Running distance with maintained RCF properties
- **Shown: Calibration run with P8 profile**
 - Mark 4 coach
 - Running distance 228 000 km
 - East coast mainline (Kings Cross – York)
- **WRISA2 RCF-relief duration approximately 100 000 km**



Industrial implementation objectives

- **Bombardier concluded the method to be sufficiently mature for industrial implementation**
- **Joint effort by Intec and Bombardier to integrate the KTH wheel wear simulation approach into Simpack aiming at:**
 - Accuracy of profile evolution prediction to be sufficient for use in MBS transient simulations
 - Possibility to estimate required reprofiling intervals with respect to wear when running on a defined network
 - Both profile shape and standard scalar wear measures to be calculated



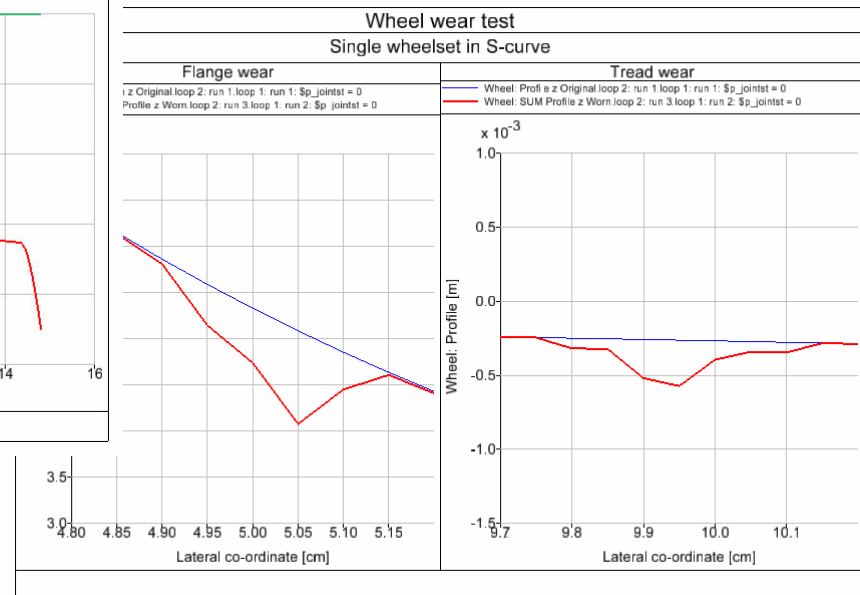
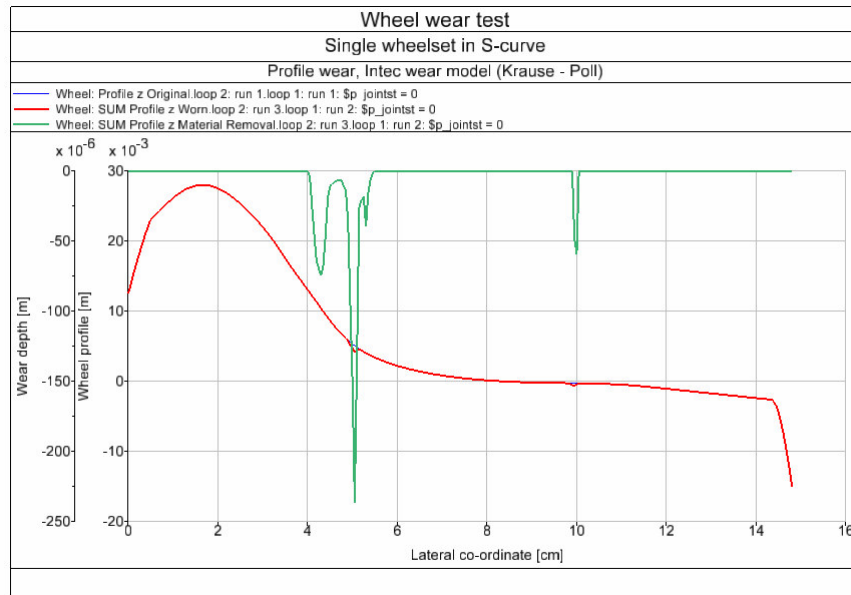
Simpack wear module structure

- **Wear model**
 - Simpack standard wear model, preliminary Krause & Poll
 - User routine interface for wear model implementation
- **Profile updating**
 - Internal wear and profile data handling
 - Wear result element for wear accumulation and profile updating
 - The (general) result element new feature in version 8800
- **Simulation set execution**
 - Simulation set variations in the ParVar innermost loop
 - Wear step control with updated profiles in the middle ParVar loop
- **Result output**
 - Standard features of the plot module via the .sbr file



Typical result layout

- Single wheelset in S-curve
- Simpack standard wear model: Krause - Poll

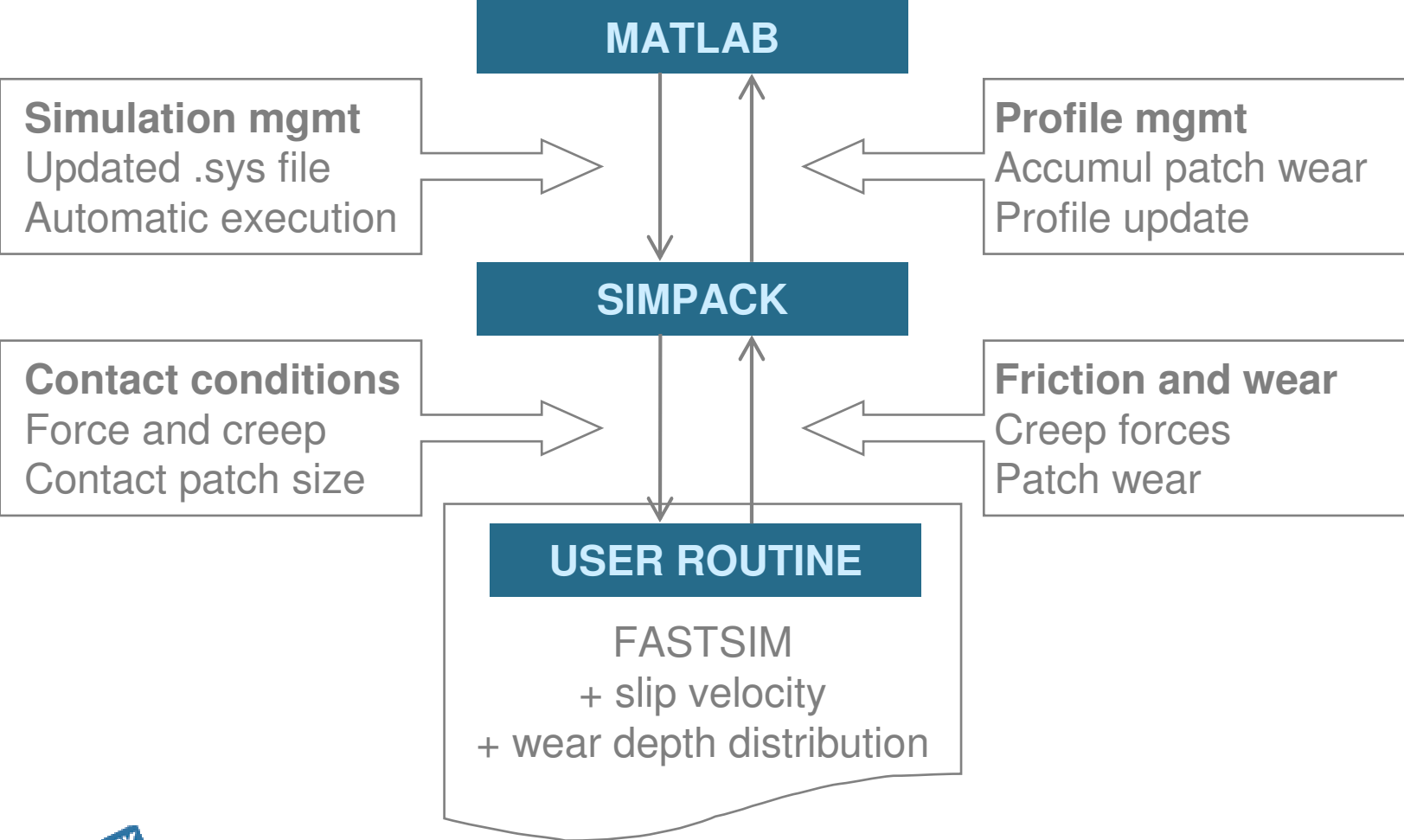


Joint implementation work packages

- **Bombardier: Initial development of Simpack interface**
 - Implementation of the wear model as a wheel/rail friction user function
 - Realisation of a temporary Matlab loop control routine for testing and initial validation
 - Temporary external automated profile updating
- **Intec: Simpack integration**
 - Internal profile and wear data handling
 - Wear accumulation and profile updating
 - Wear user routine interface
 - Extension of the parameter variation facility to handle the wear simulation set and loop control



Structure of temporary solution



Elementary testing

- **Compatibility with Simpack contact models**

- Elastic contact with on-line contact data calculation preferable
- Problems with the rigid flange contact calculation in case of two-point contact
- The s-var rail profile methodology necessary for multi-point contact conditions
- Results sensitive to regularisation parameter setting in the quasi-elastic contact data generation

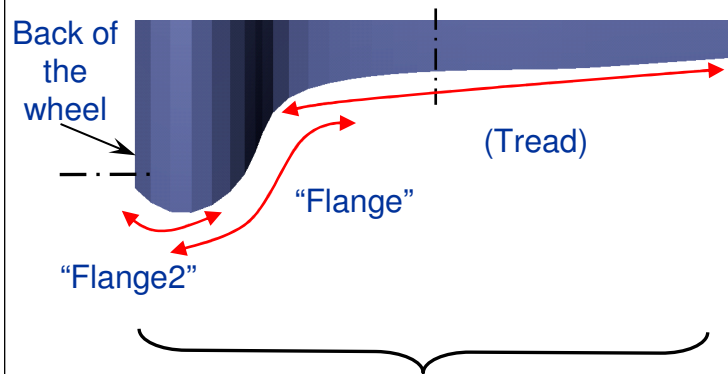
- **Profile updating**

- Shaping of the wear distribution critical due to possible interference with the profile approximation
- Simulation time sensitive to the profile quality

Difference between s-variable and s-constant profiles

s-Variable Profiles

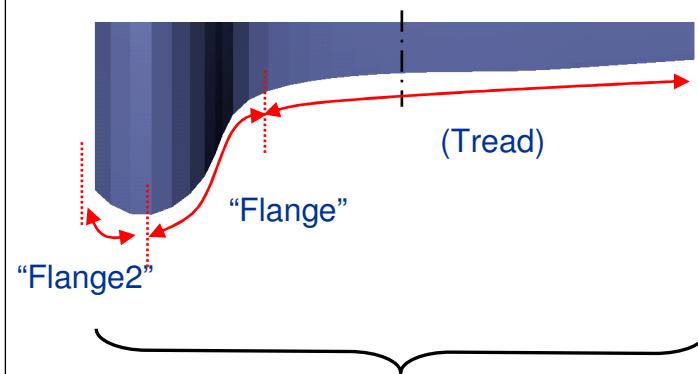
Contacts may act anywhere on profile



- Constraint or elastic contact
- Back of the wheel: Only elastic contact
- Quasi-elastic contact data generation on-line

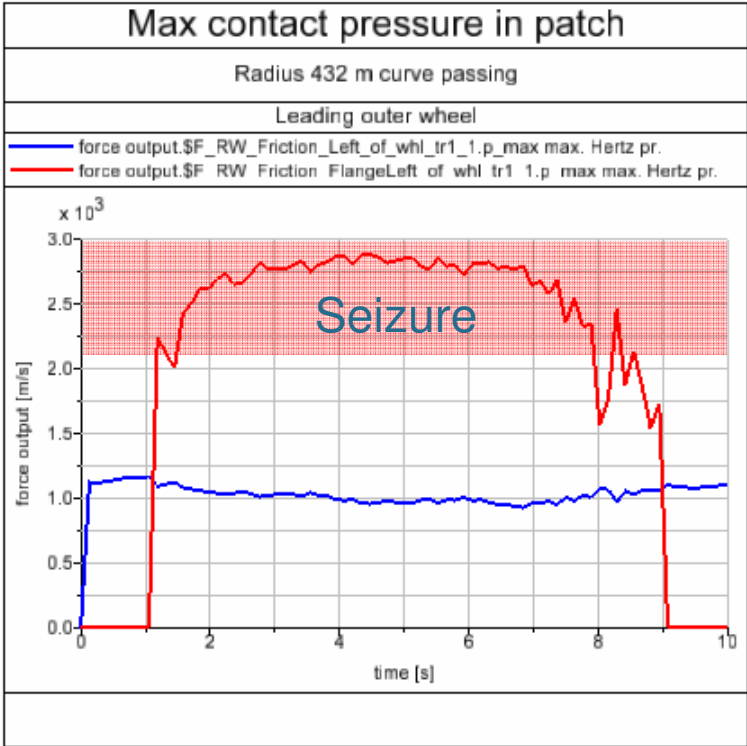
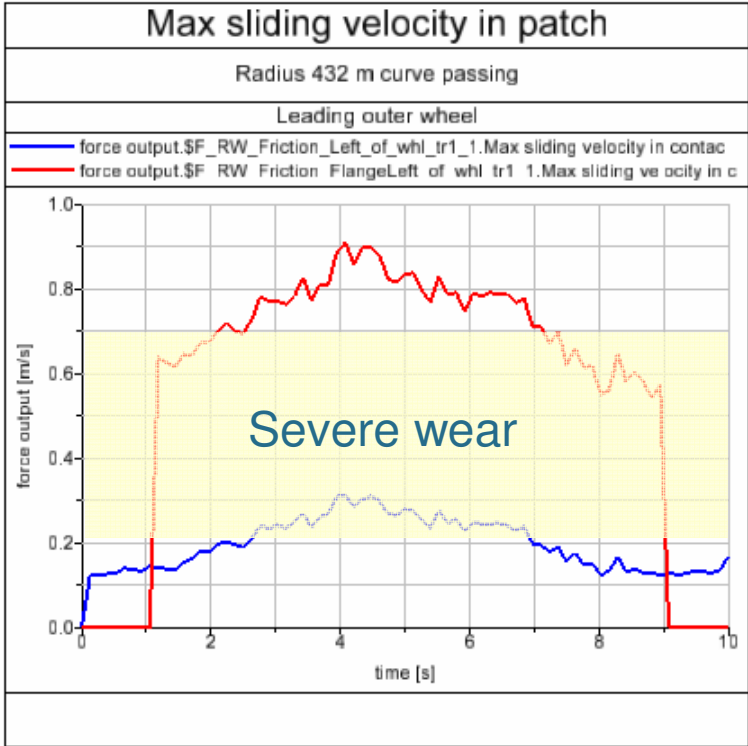
s-Constant Profiles

Contacts act only in their designated profile sections



- Constraint or elastic contact
- Tread: Quasi-elastic or rigid contact data by table
- Flange: Rigid contact data generation on-line

Contact patch condition examples



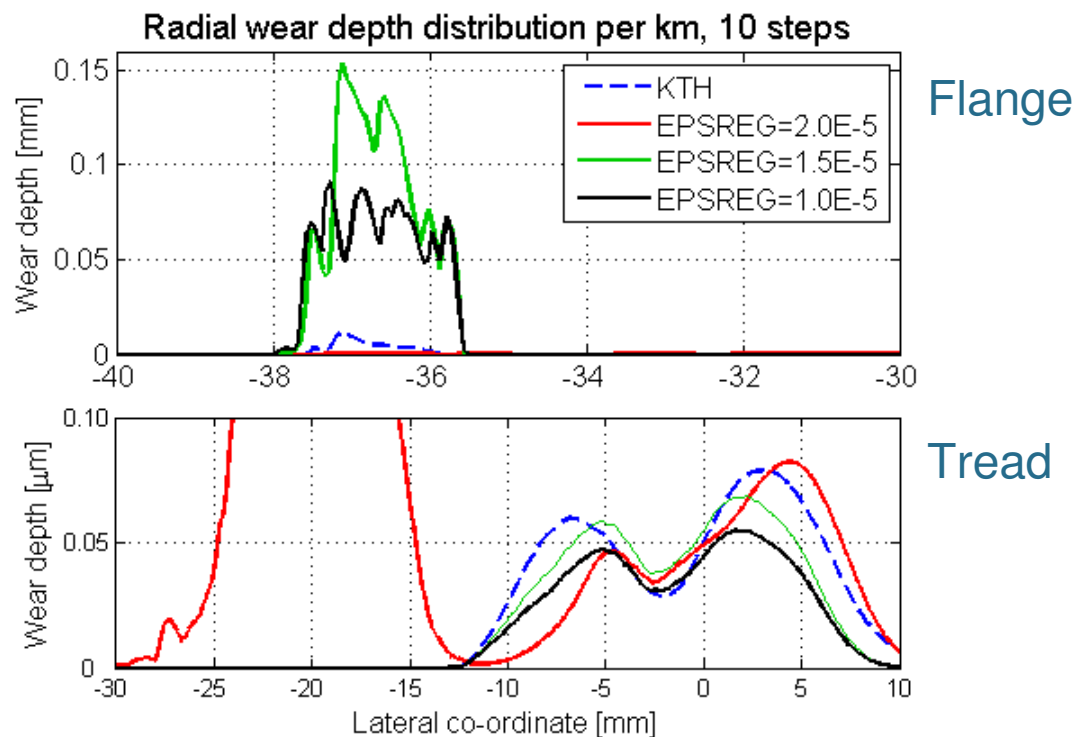
— Tread contact

— Flange contact



Emerging validation

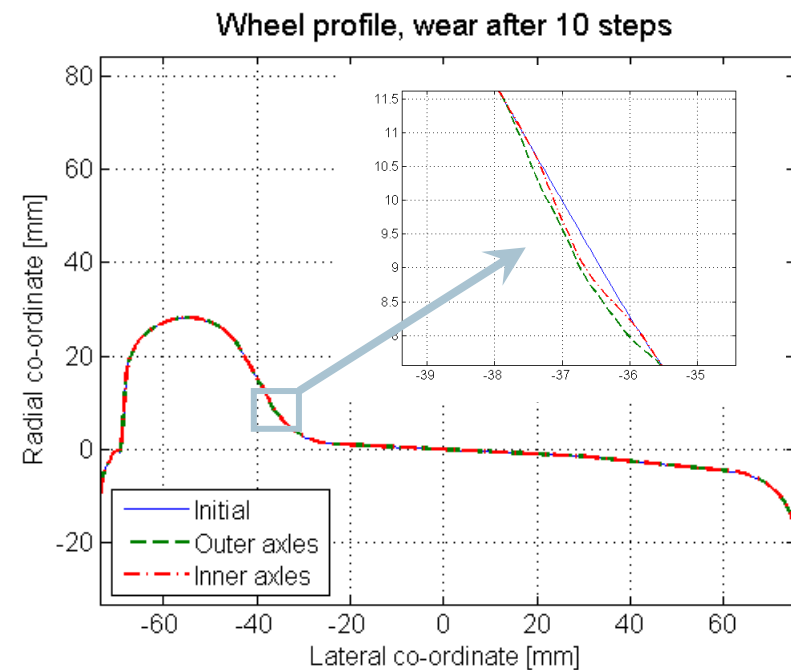
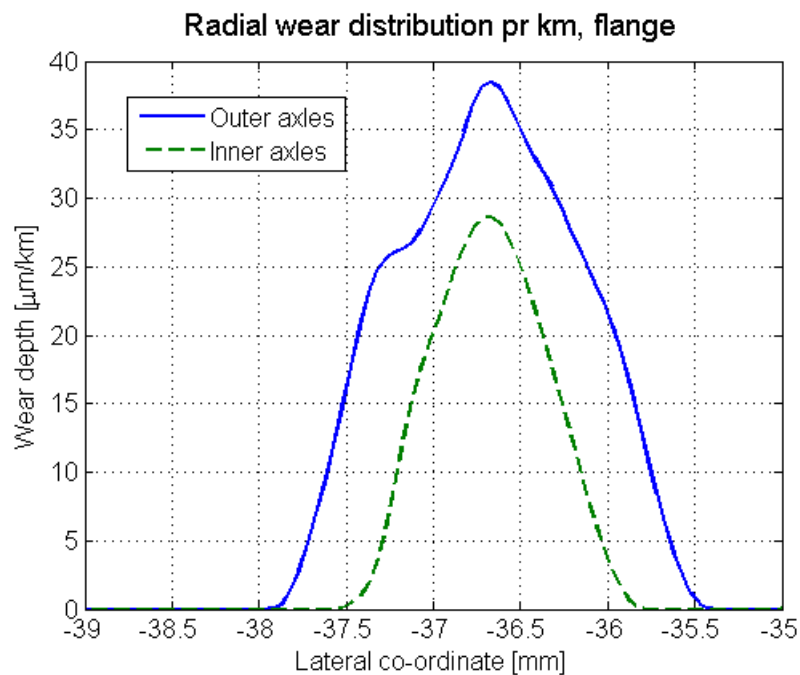
- **Wear rate in comparison to the KTH reference case**
 - Tread wear comparable
 - Flange wear excessive due to critical contact stress (seizure)



Reference case example

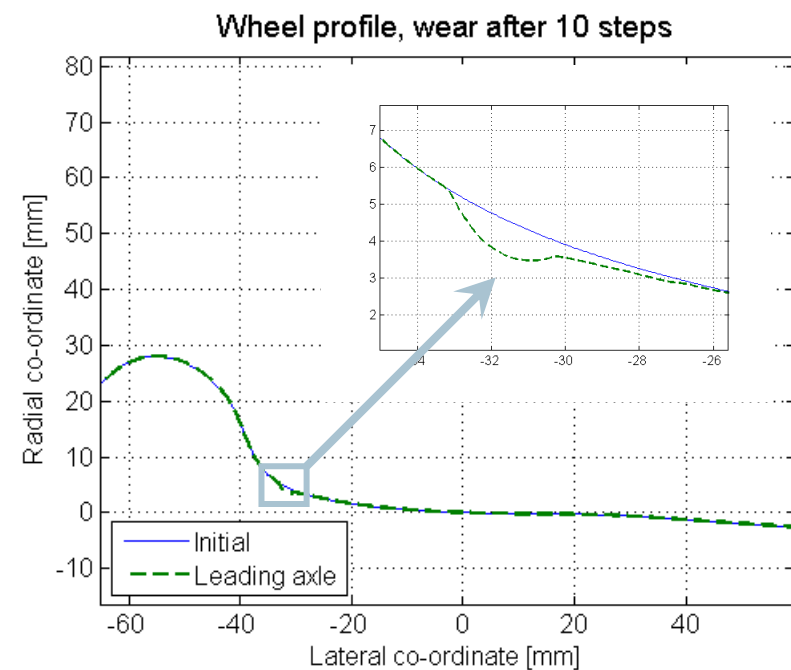
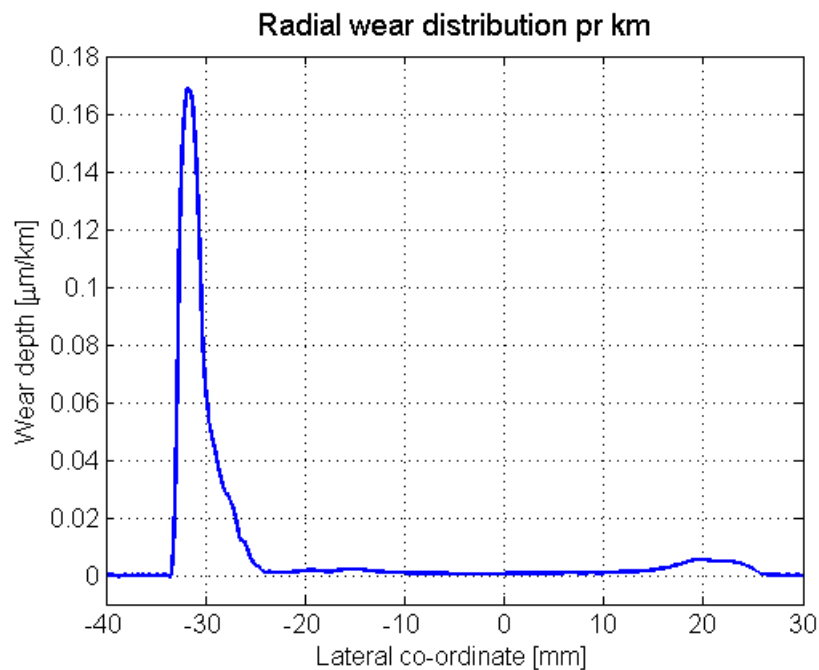
- **Flange wear distribution per rolled distance**

- Reduced simulation set (8 simulations/step)
- Based on 10 steps, 14 km
- Straight cone profile, 1:20 tread, 60° flange, two-point contact



Reference case example

- **Flange wear distribution per rolled distance**
 - Reduced simulation set (8 simulations/step)
 - Based on 10 steps, 5677 km
 - S1002 initial profile



Conclusions

- **Wear simulation concept works**
- **Flange wear rate high**
 - Sliding velocities comparable
 - Contact pressure critical with respect to seizure
 - Re-evaluate contact mechanics and wear model settings
- **Simulation time long**
 - Short wear steps due to distorted profile geometry
 - S-variable rail profiles necessary for multi-point contact cases
 - Use local smoothing of worn geometry
- **New wheel/rail contact element essential**
 - Multi-point contact consistency and efficiency
 - EPSREG setting not critical