SIMPACK User Meeting
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Towards railway wheel performance prediction by simulation

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Outline

- **Background**
- **Wheel-rail interface performance**
- **Emerging prediction methods**
  - Wear prediction
  - Rolling contact fatigue assessment
- **SIMPACK implementation**
- **Applications**
  - Hollow wear
  - Rolling contact fatigue
  - Accumulated fatigue damage
- **Wheel-rail contact issues**
- **Conclusions**

Market requirements

- **Increased performance requirements on wheels**
  - Higher axle loads
  - Higher braking and traction forces
  - Higher dynamic loads due higher speeds
  - Smaller wheels
- **Increased focus on maintenance costs**
  - Wheel deterioration is in the top 10 of maintenance cost drivers
- **Track access charges being differentiated towards track damage dependency**
- **Increased interoperability between different track systems with different rail standards**

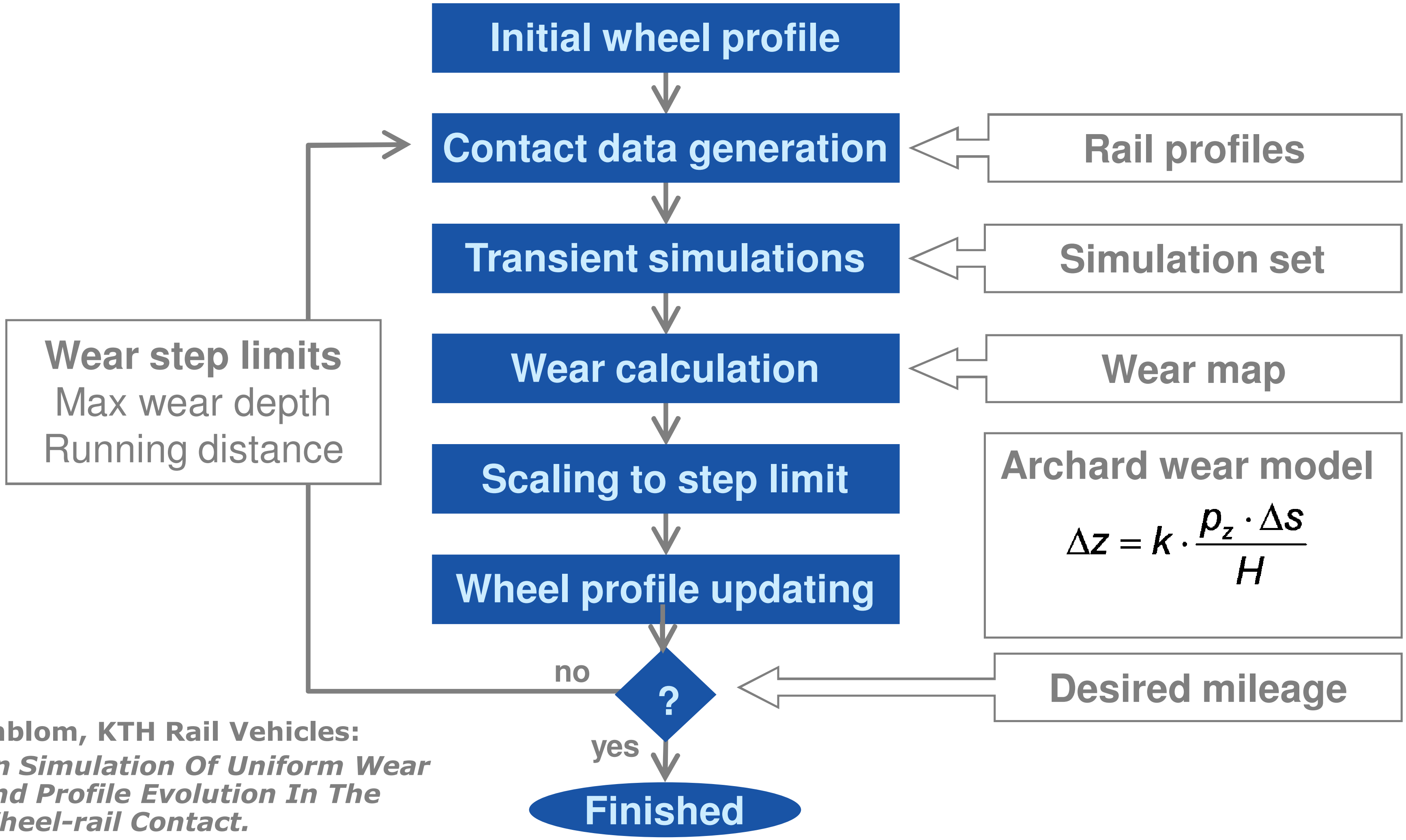
Modes of deterioration

- **Rolling contact fatigue (RCF)**
  - Shelling, spalling, head checking, fracture
- **Adhesive or abrasive wear**
  - Material loss, altered profile geometry
- **Plastic deformation**
  - Material relocation, ratchetting
- **Phase transformation**
  - Altered material properties, martensite
- **Mode interactions**
  - Out-of-roundness, corrugation

Emerging technologies

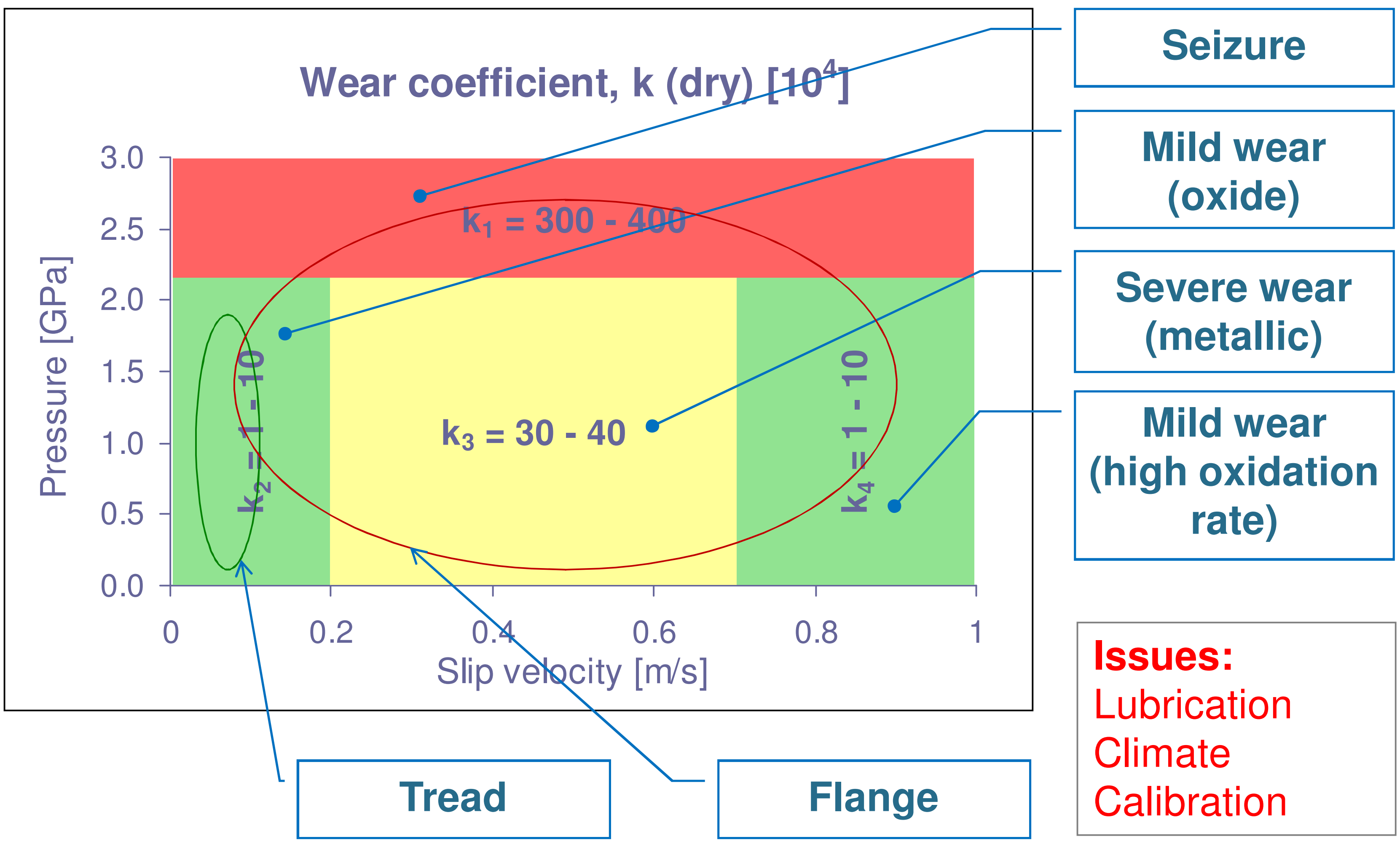
- **Wheel profile wear prediction procedure based on Archard's wear model**
  (Royal Institute of Technology, Sweden)
- **Empirical RCF risk assessment method including influence of wear**
  (Delta Rail for RSSB, UK)
- **Engineering model for RCF risk assessment based on shake down properties**
  (Chamers Technical University, Sweden)

Wheel wear simulation procedure



Enblom, KTH Rail Vehicles:
On Simulation Of Uniform Wear And Profile Evolution In The Wheel-rail Contact.

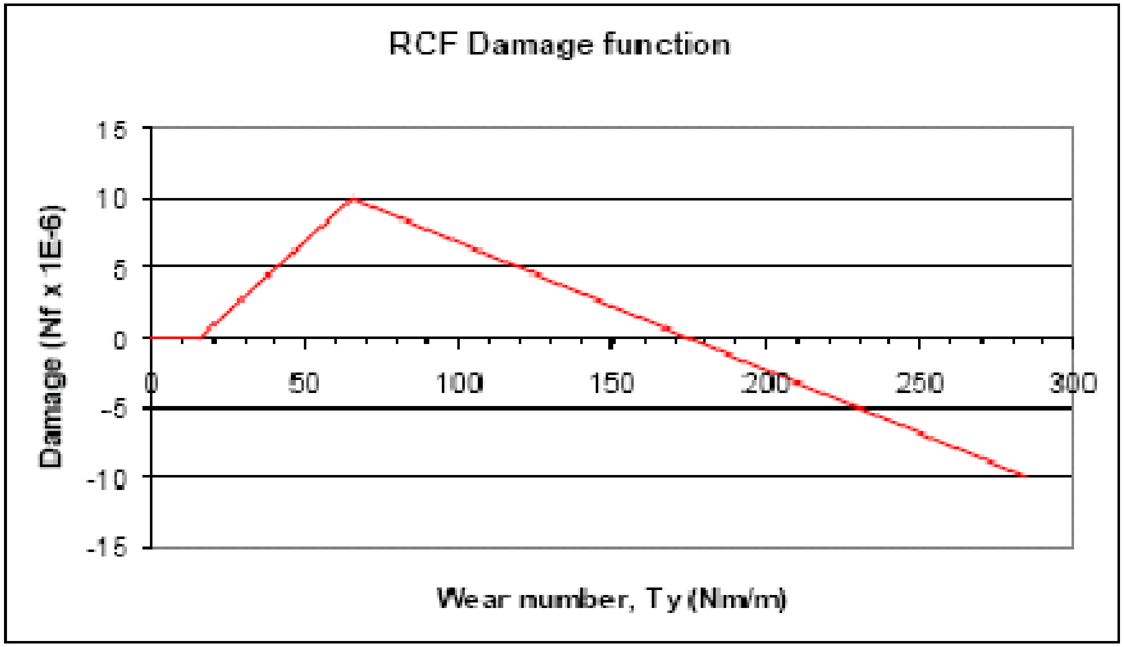
Map of wear coefficients



Issues:
Lubrication
Climate
Calibration

Empirical RCF damage model

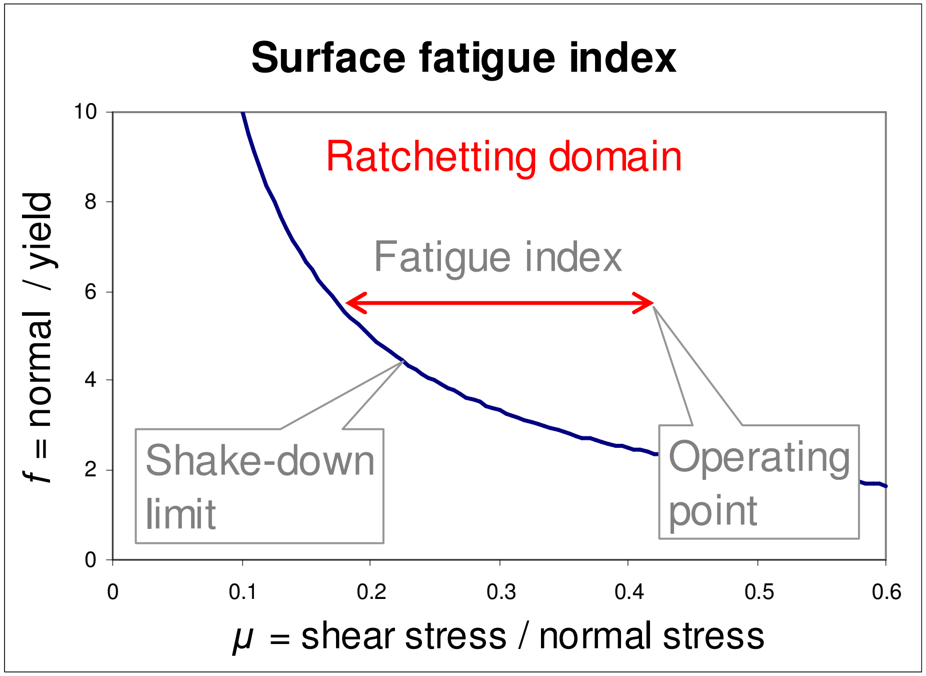
Combined fatigue/wear damage related to energy dissipation



Issues:
Fatigue life
Calibration
Contact pressure

Burstow, Delta Rail (for RSSB):
Whole Life Rail Model Application and Development for RSSB – Continued Development of an RCF Damage Parameter

Engineering criterion for surface fatigue



Risk criterion:

$$FI_{surf} = \mu - p_0/k < 0$$

μ = traction coefficient

p_0 = contact pressure

k = yield strength in shear

Issues:

Fatigue life

Crack depth

Creep

Ekberg, Kabo, Chalmers Applied Mechanics :

An Engineering Criterion for Prediction of Surface Initiated Rolling Contact Fatigue.

SIMPACK implementation

- **SIMPACK development (public parts)**
  - Internal profile and wear data handling
  - User routine interface for wear model implementation
    - Krause & Poll wear model
    - Wear accumulation and profile updating
  - Extension of the parameter variation facility to handle the wear simulation set and loop control

SIMPACK implementation

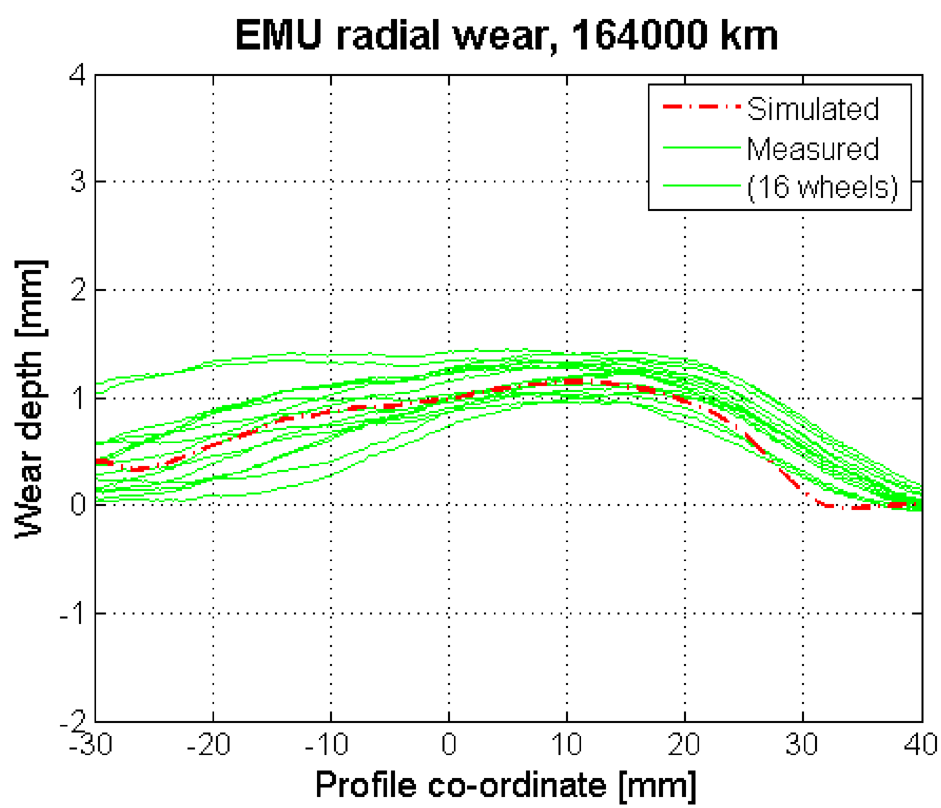
- **BT development (proprietary parts)**
  - Implementation of wear model as proprietary user functions
    - Contact patch discretisation and local contact condition calculation
    - Archard’s wear model
    - Automatic wear step control
    - Running distance calculation
  - Implementation of RCF criteria as proprietary user functions
    - Shake down model
    - RSSB damage function
  - Software procedure testing
  - Quantitative validation with reference operations

Representation in SIMPACK Virtual Test Lab

- **Simulation set in the innermost loop**
  - Controlled by ParVar steering files
  - Selecting predefined database tracks
  - Selecting track irregularity files
  - Further parameters to be varied in parallel, for instance speed, weighting factors, simulation time, number of output points, …
  - Varying of rail profiles
  - Variation of any substitution variable
- **Profile variation in the outer loop**
  - Dummy parameter to define number of profile updates

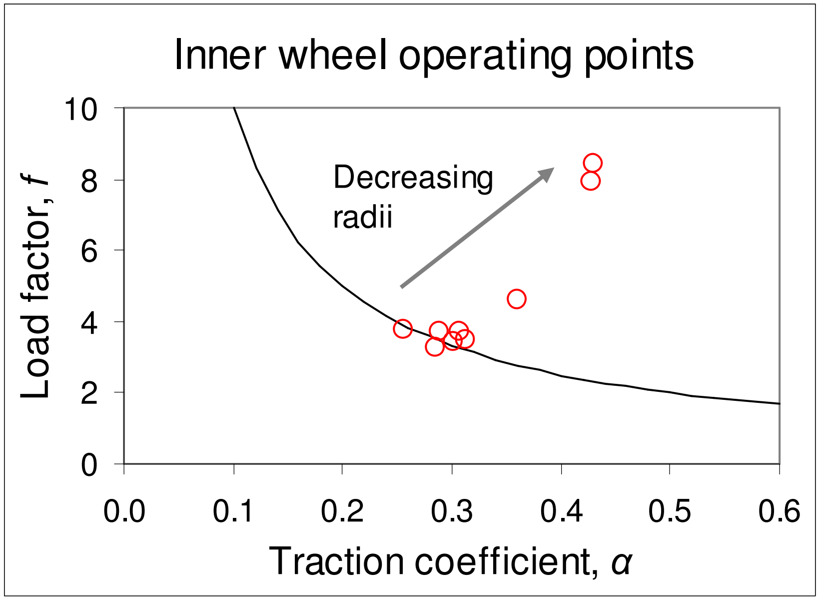
Application – Hollow wear

- **14 simulations per step (164000 km, 364 steps)**
  - Curves and tangent
  - Tractive forces
- **Calibration of wear map**
  - Ambient conditions
  - Contact modelling
- **Corrective actions**
  - Improved yaw dampers
  - Monitoring of profile shapes



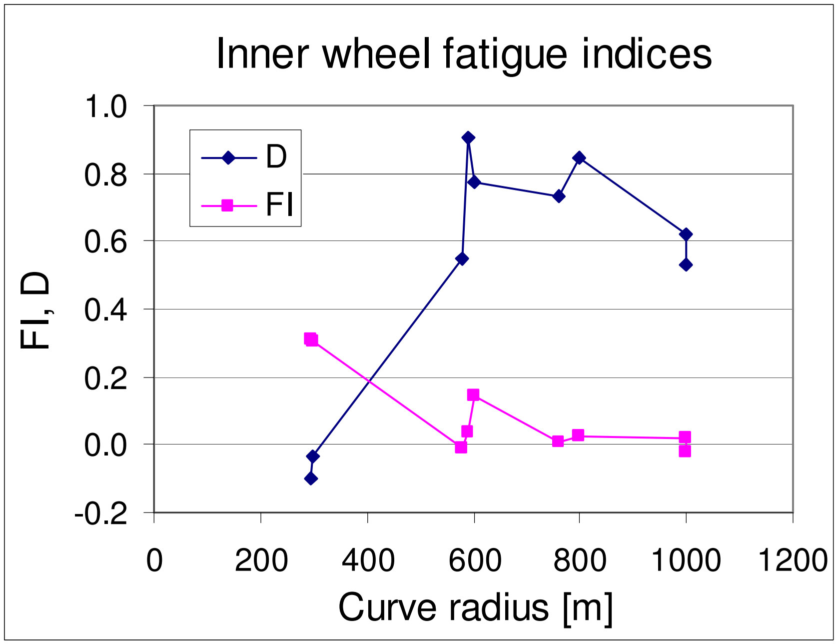
Application – Rolling contact fatigue

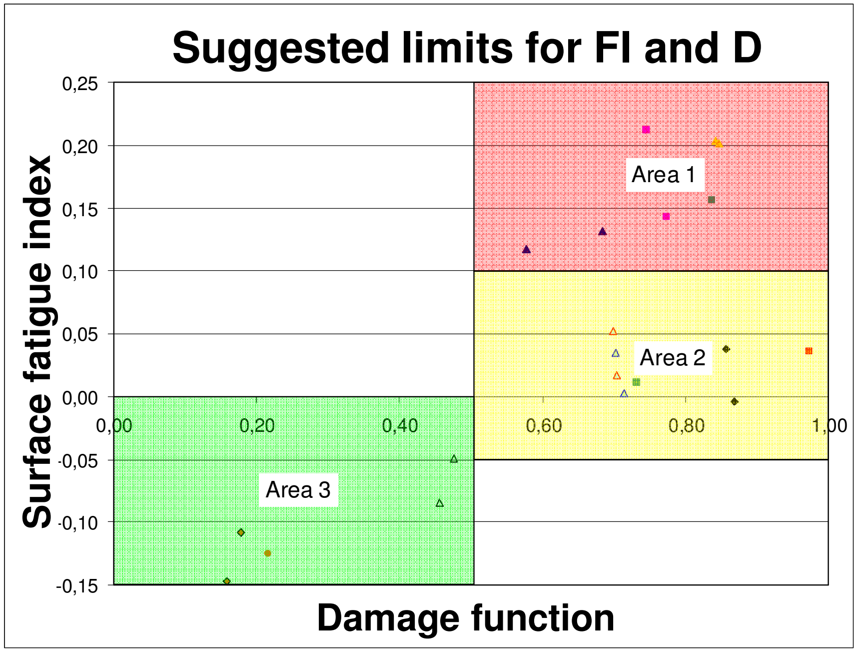
- **Three vehicles with different occurrence of RCF**
- **Evaluation of fatigue indices against reality**
  - Significance of wheel profile
  - Significance of wear
- **Quasi-static curving**
  - Curve radii 300 – 1000 m



Application – Rolling contact fatigue

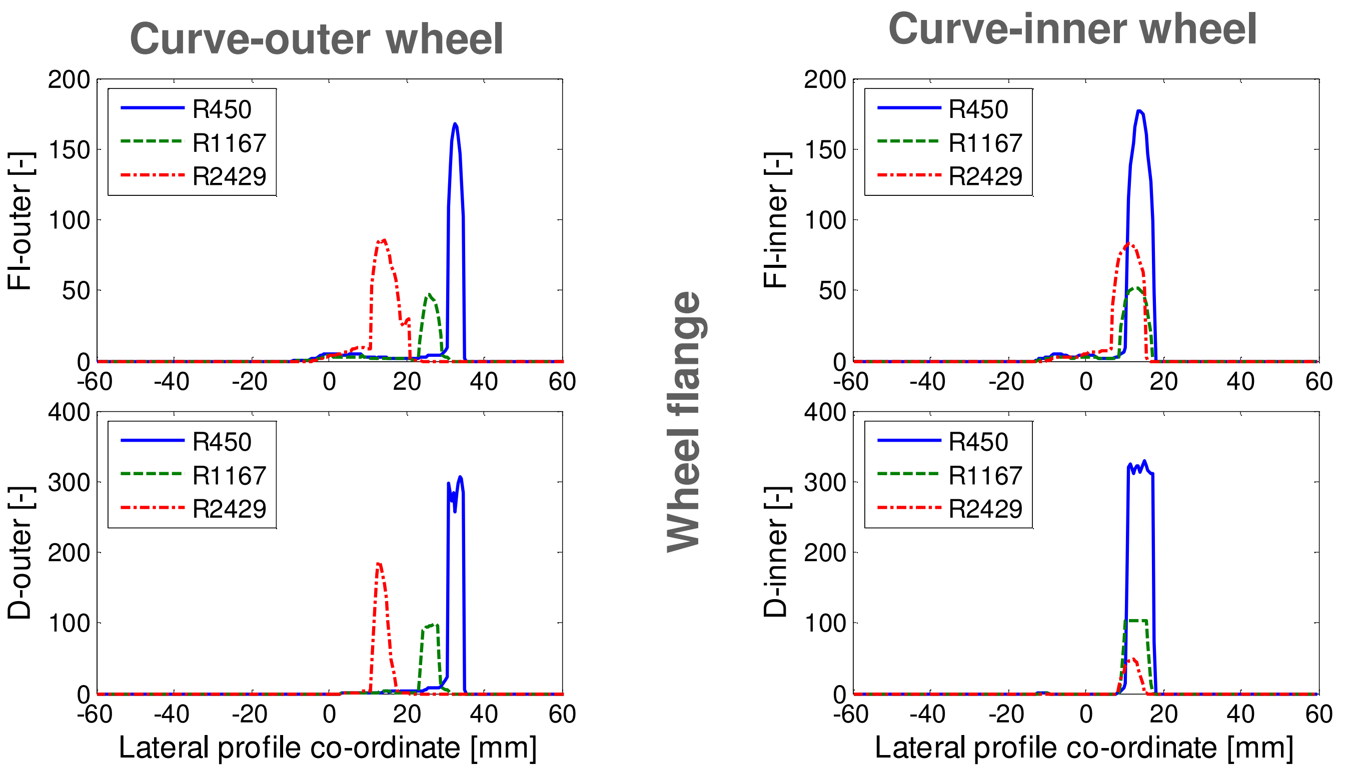
- Both indices have pros and cons
- An attempt to classify RCF risk
- Calibration needed





Application – Fatigue accumulation

- **High speed train during curve negotiation**
  - Accumulated wear indices



SIMPACK contact modelling

- **Classic contact modelling experience**
  - One-point contact with quasi-elastic model works well
  - Standard multi-point contact may cause problems due to the rigid flange contact approach (difficulties to find the correct contact location on wearing profiles)
  - The all-elastic s-variable contact approach is more stable for multi-point cases
  - The contact position and wear depth at the flange may be sensitive to the quasi-elastic regularisation setting (EPSREG)
- **New wheel / rail contact model being tested**
  - Variable number and arbitrary location of contact points
  - Expected to ease the difficulties experienced so far
- **Non-elliptic / conformal contact not available**

Conclusions

- **The effort to implement academic results in engineering should not be underestimated**
- **Experienced methods have been helpful in gaining understanding of the deterioration processes**
- **Wear models reasonably well calibrated for normal operating conditions**
- **RCF models indicate risk for appearance**
- **Improvements needed**
  - Contact model
  - Wear maps for extended range of contact conditions
  - Fatigue life model