

CHALMERS

UNIVERSITY OF TECHNOLOGY

CHARMEC MU40

DIGITAL TWINS OF

REPROFILED RAILS

CAROLINE ANSIN

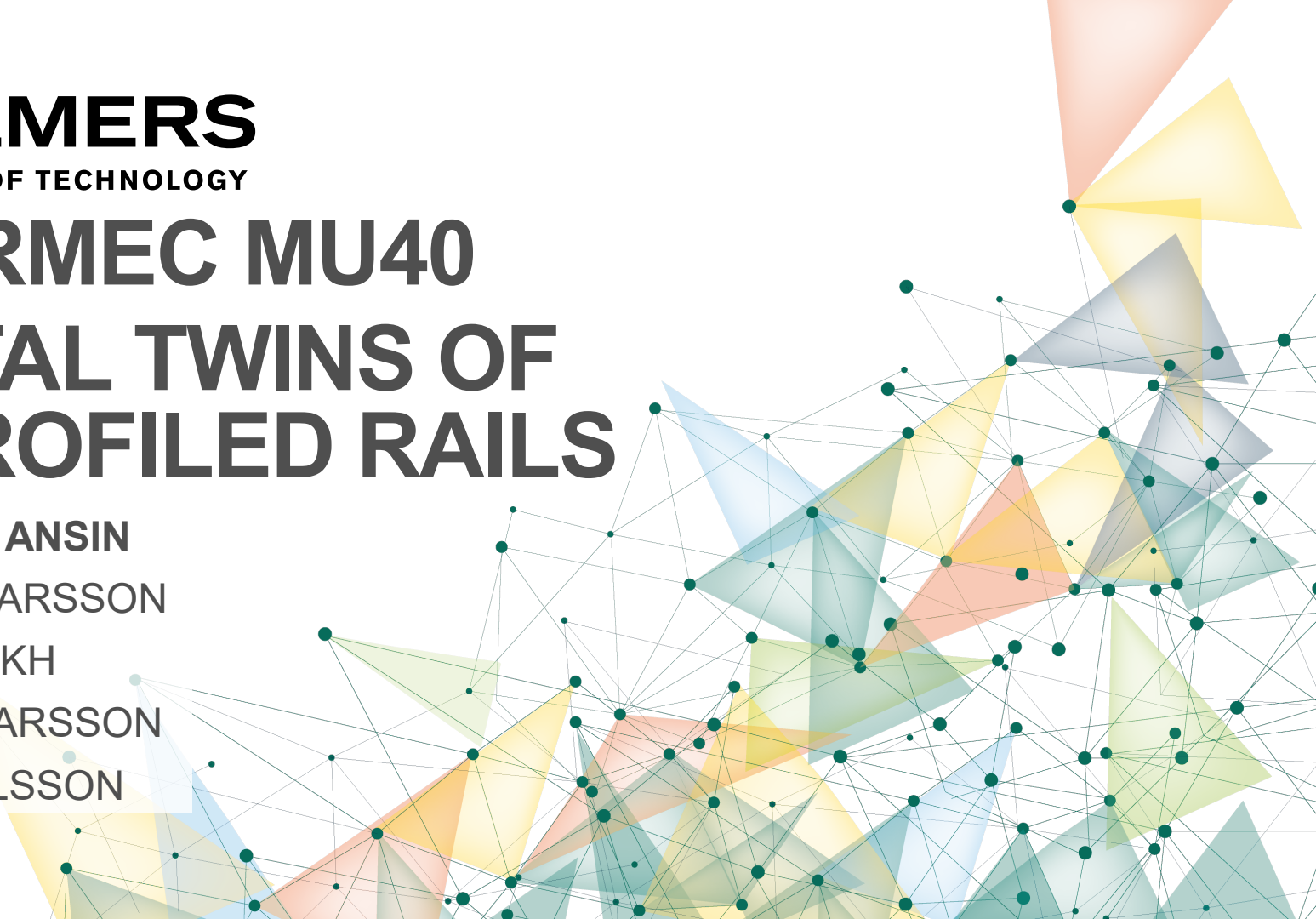
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AG 60 – Rälssvetsning: Digitala tvillingar – övervakning av växlar Condition based monitoring of Switches and Crossings (S&C)

Charmec projekt:

- Utveckla en modellbaserad numerisk procedur som kan identifiera det strukturella tillståndet för växlar och korsningar (S&C) genom att använda inbäddade sensorer.
- Systemet kan beskrivas som en **Digital tvilling**-representation av det fysiska systemet, där **simuleringsmodeller**, tillståndsovervakningsdata och underhållshistorik kombineras för att förutsäga och identifiera underhållsbehov för S&C.
- **Digital tvilling**: En **digital modell av (till exempel) en S&C**. Den kan få information från den fysiska modellen (den verkliga S&C) som uppmätt faktisk geometri, belastningar och användas för förutsägelser av deformationer, skador, dvs **övervakning av S&C: s underhållsbehov**.

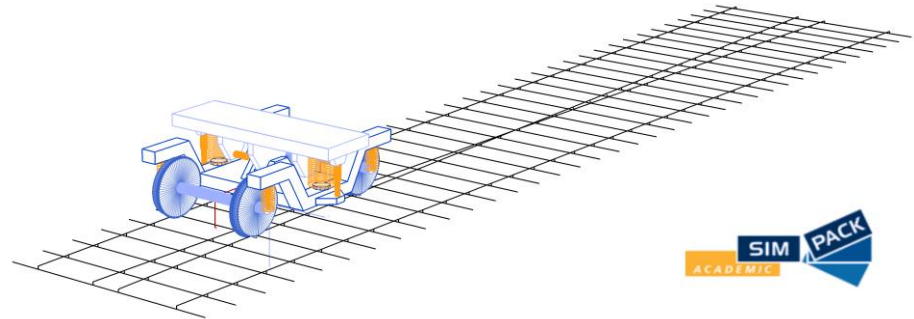
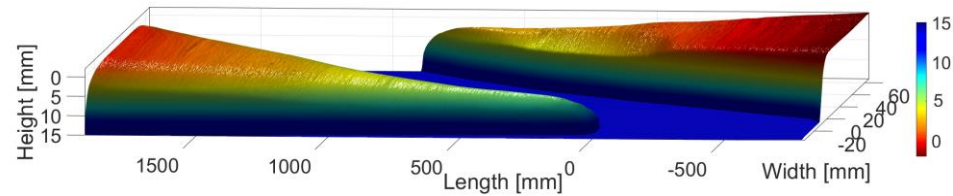
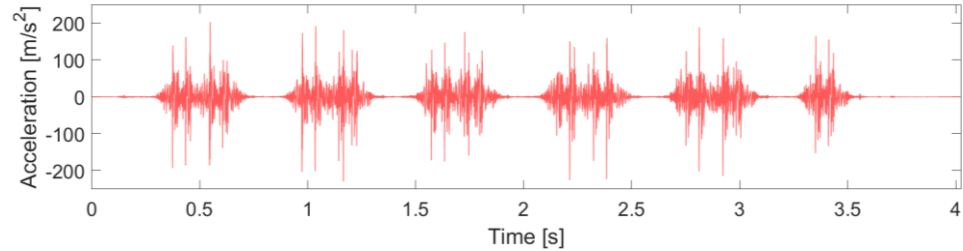
Project TS21 Marko Milosevic

- **Model-based condition monitoring of railway switches and crossings**
 - The aim of the project is to develop a Digital Twin solution for switches and crossings where simulation models, condition monitoring data and maintenance history are combined to identify and predict the maintenance needs for S&C.
- **Continuous collaboration with Trafikverket and Arne Nissen**
- **Experimental data**
 - Sleeper displacement reconstruction
 - Displacement signatures
 - Train type identification
 - Crossing geometry scans



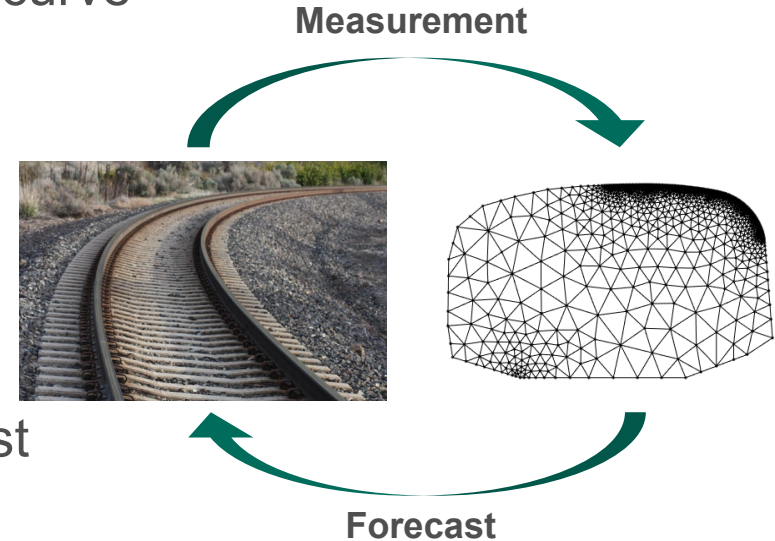
Approach

- **Experimental analysis**
 - Two types of condition monitoring data are obtained in the field
 - Sleeper accelerations from embedded sensors
 - 3D scans of crossing surface geometry
- **Numerical analysis**
 - Multi Body Dynamics (MBD) models are used to simulate crossing transitions
 - 3D crossing rail geometry is implemented in MBD
 - Validation and calibration based on experimental data



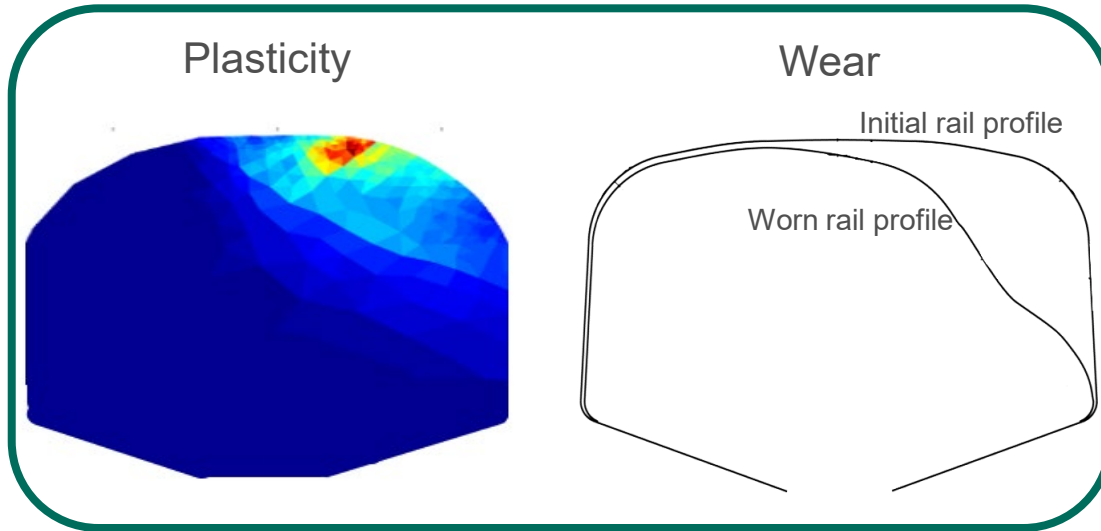
DIGITAL TWIN CONCEPT

- Develop a **digital twin** to model the evolution and degradation of ground rail under operational traffic in a curve
- **Digital twin** = Numerical model of a physical counterpart
- **Model updating** from field measurements
- **Prediction** of different scenarios
- Develop a **reduced order model** for fast simulations.
- **Decision tool** for maintenance of rails



RAIL DETERIORATION

- Study the geometry changes of a ground rail due to:



Estimate crack initiation
& formation



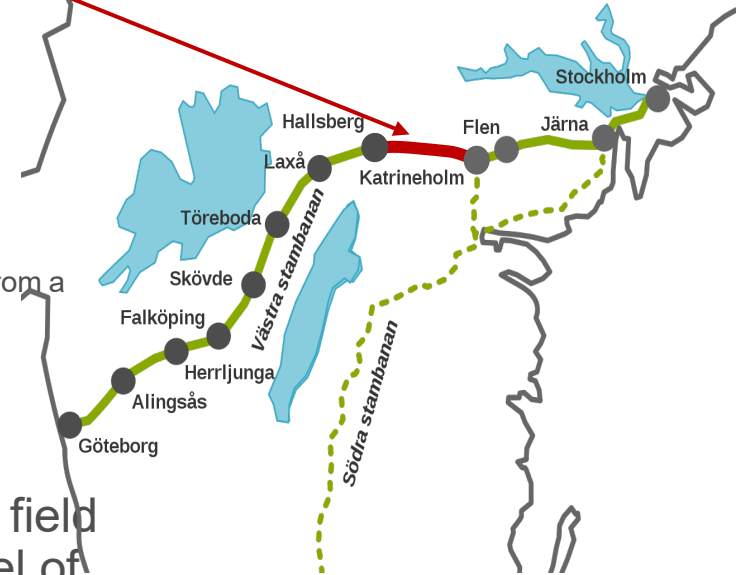
- Compare to measurements and update numerical model

SPECIFIC GOALS

1. Establish a **digital twin** of a rail section in a curve.
2. Develop a **reduced order model** for efficient simulations during a high number of load cycles.
3. Incorporate **model updating** based on geometry measurements
4. **Predict** (forecast) **geometry changes** (plasticity and wear) and crack formation under current and/or updated operational conditions

FIELD MEASUREMENTS (TRAFIKVERKET)

- Measurements at **Västra Stambanan** (Nyckelsjön-Sparreholmen)
 - Two different segments are considered
 - Curve radius between $900 < R < 2000\text{m}$
 - Different damage characteristics
 - Mixture of new and ground rail
- **Profile measurements**
 - Laser - Measurement every 25 cm, rail profile is estimated from a moving average
 - Miniprof - Measurement approximately every 60 m
- **Crack detection** (eddy-current)
- Outcome/goal: Compare simulated data with field measurements to update the numerical model of the digital twin framework



SIMULATION TOOL

- Simulation tool to predict **long term rail damage evolution** (plasticity and wear) developed in CHARMEC (project TS17)

1. Dynamic vehicle-track interaction

- Contact position, forces & creepages
- FASTSIM algorithm & Hertz method

2. Normal contact problem (Metamodel)

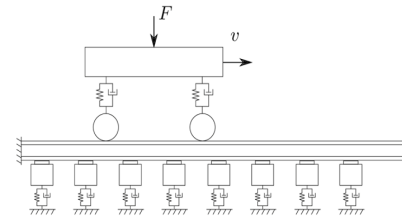
- Detailed information of contact stresses

3. Damage evolution

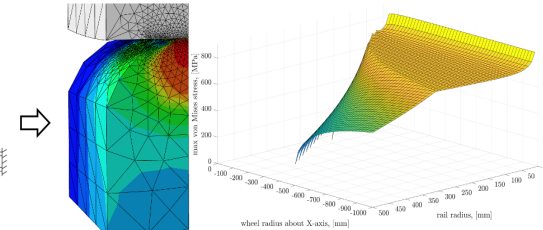
- Plastic deformation (FE-plane strain model)
- Wear (FASTIM & Archard's wear law)

4. Profile update

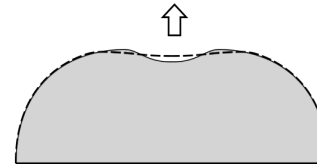
→ **Crack initiation & formation (future work9)**



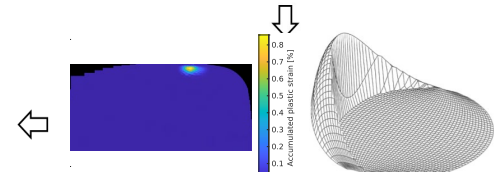
1. Dynamic vehicle-track interaction



2. Metamodel of elasto-plastic contact



4. Profile update

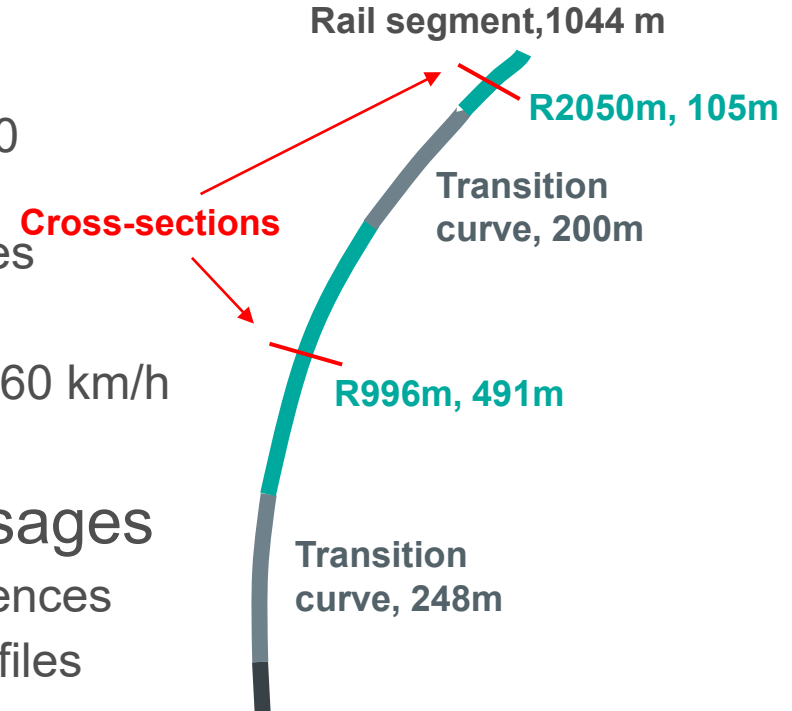


3. Damage evolution

5. Crack initiation & formation (future work)

SET UP - INITIAL SIMULATION

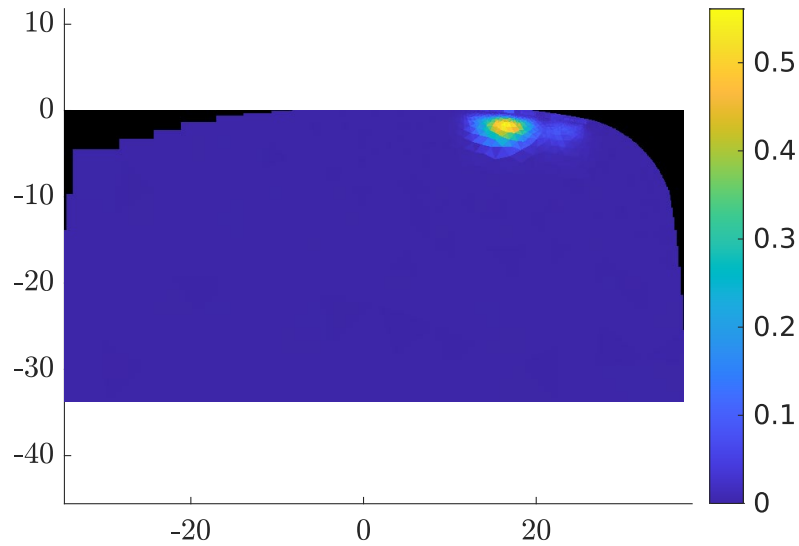
- Set up:
 - Rail grade R260, MB4 profile, 1:30 inclination, no track irregularities
 - Passenger train, axle load 14 tones
 - Friction coefficient: $\mu=0.35$
 - Speed: $v=110$ km/h (R996m), $v=160$ km/h (R2030m)
- Simulated for 1200 wheel passages
 - 100 vehicles x 4 wheels x 3 sequences
 - 100 different measured wheel profiles



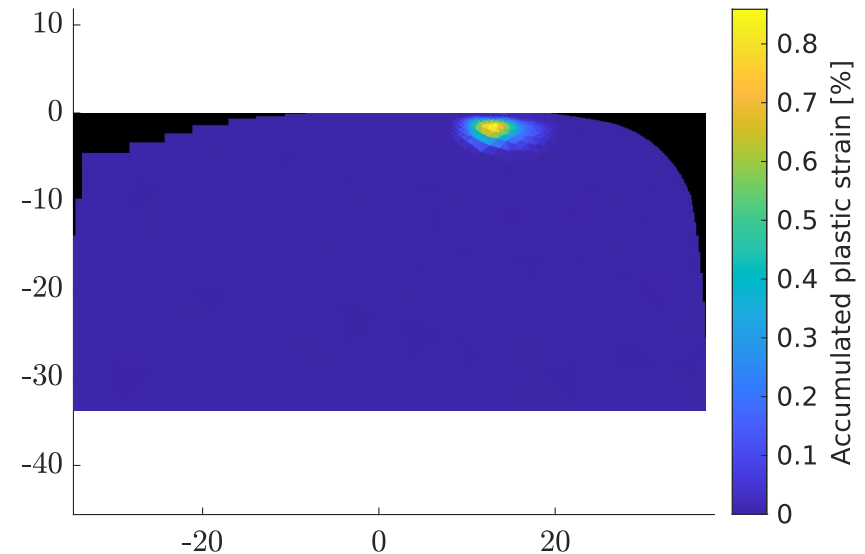
PLASTIC DEFORMATION - INITIAL RESULTS

- Convergence issue in plasticity simulation for the smaller curve radius

Accumulated plastic strain, $R=996\text{m}$ $v=110\text{km/h}$

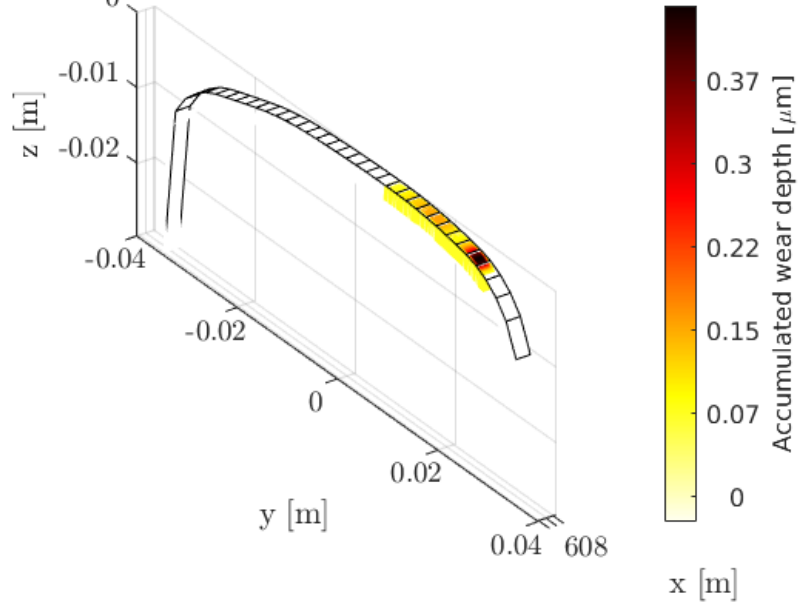


Accumulated plastic strain, $R=2030\text{m}$ $v=160\text{km/h}$

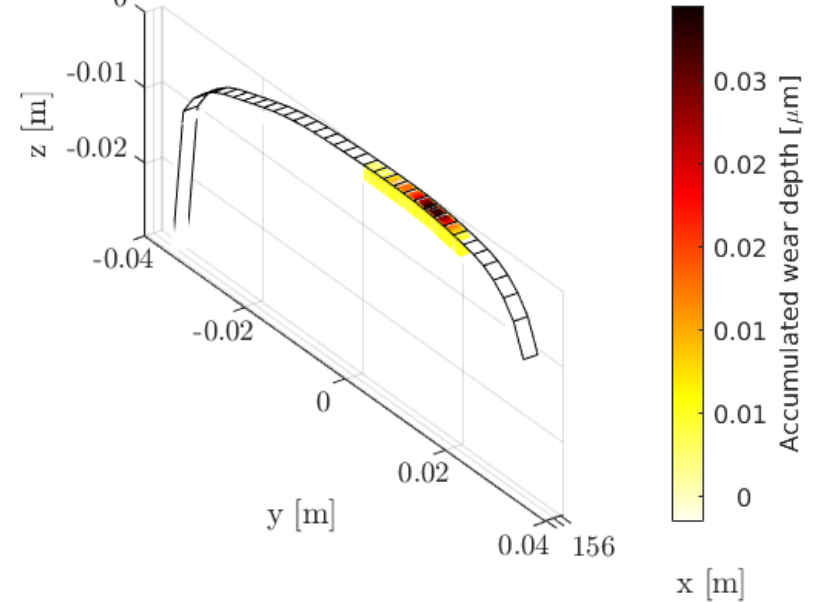


WEAR - INITIAL RESULTS

Accumulated wear depth, $R=996\text{m}$ $v=110\text{km/h}$

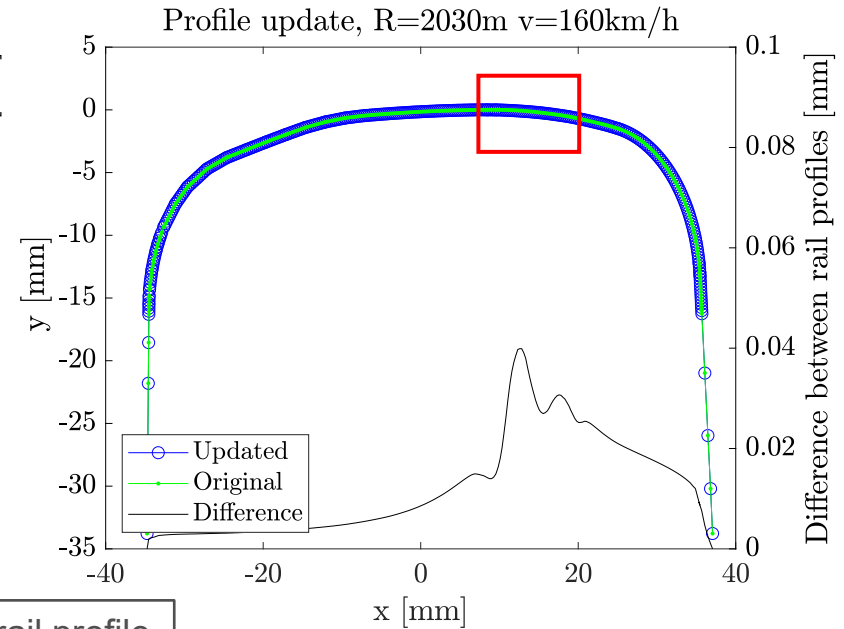
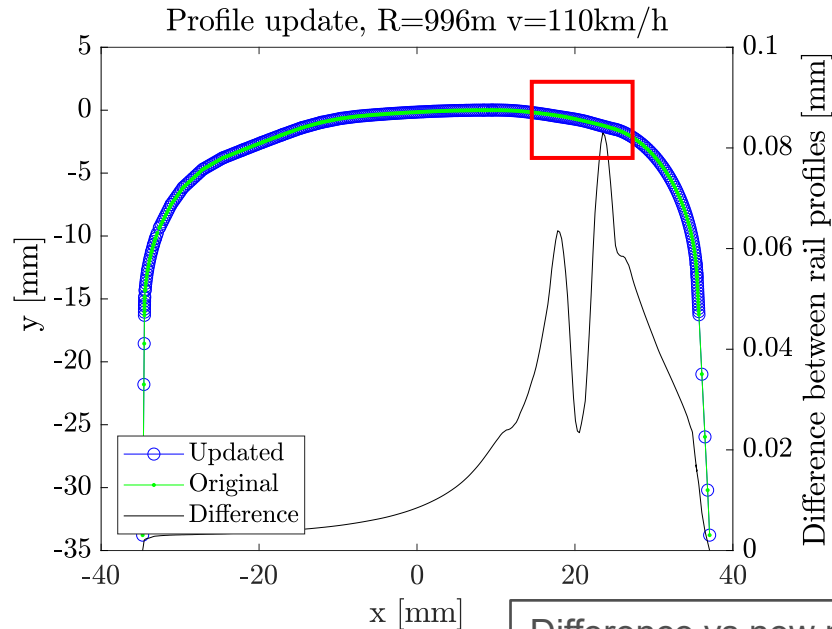


Accumulated wear depth, $R=2030\text{m}$ $v=160\text{km/h}$



TOTAL GEOMETRY CHANGE – INITIAL RESULTS

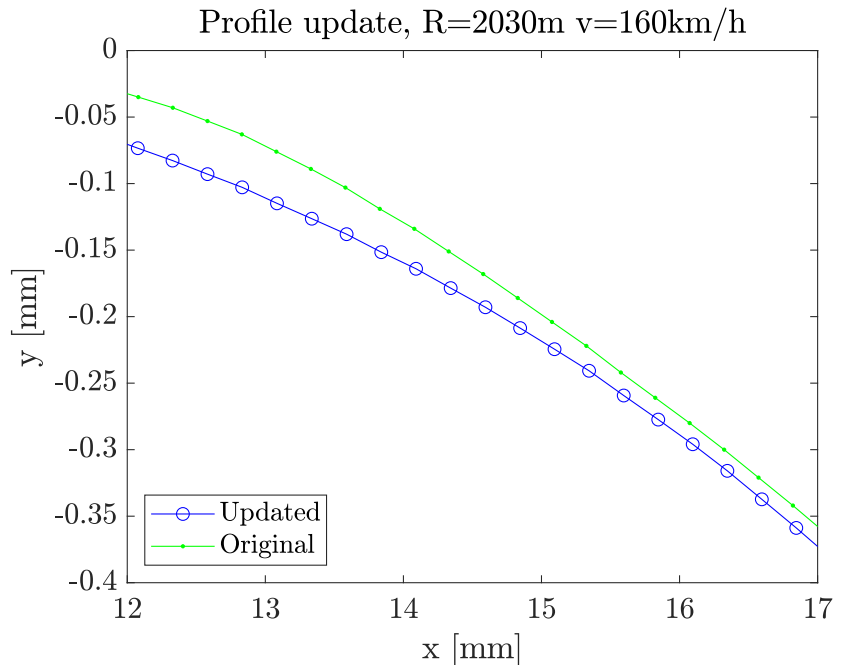
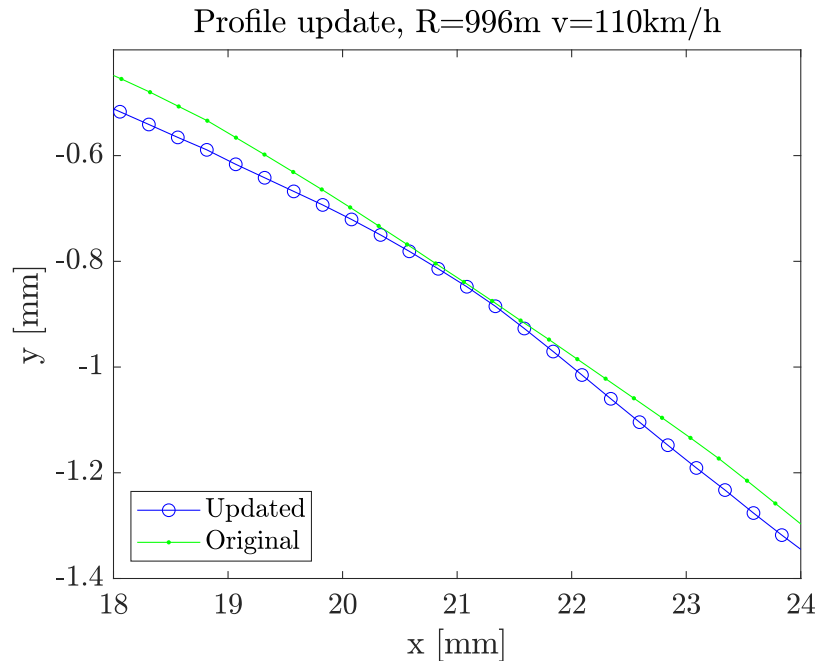
- Geometry change due to plasticity and wear:



Difference vs new rail profile

TOTAL GEOMETRY CHANGE – INITIAL RESULTS

- Geometry change due to plasticity and wear:



FUTURE WORK

- Paper 1: Long term rail damage evolution in a curve
 - Representative load collective
 - Simulate for a higher amount of load cycles
 - Implement model to estimate crack initiation and formation
 - Compare results against field measurements
- Implement digital twin framework
 - Incorporation of measurements
- Reduced order model