

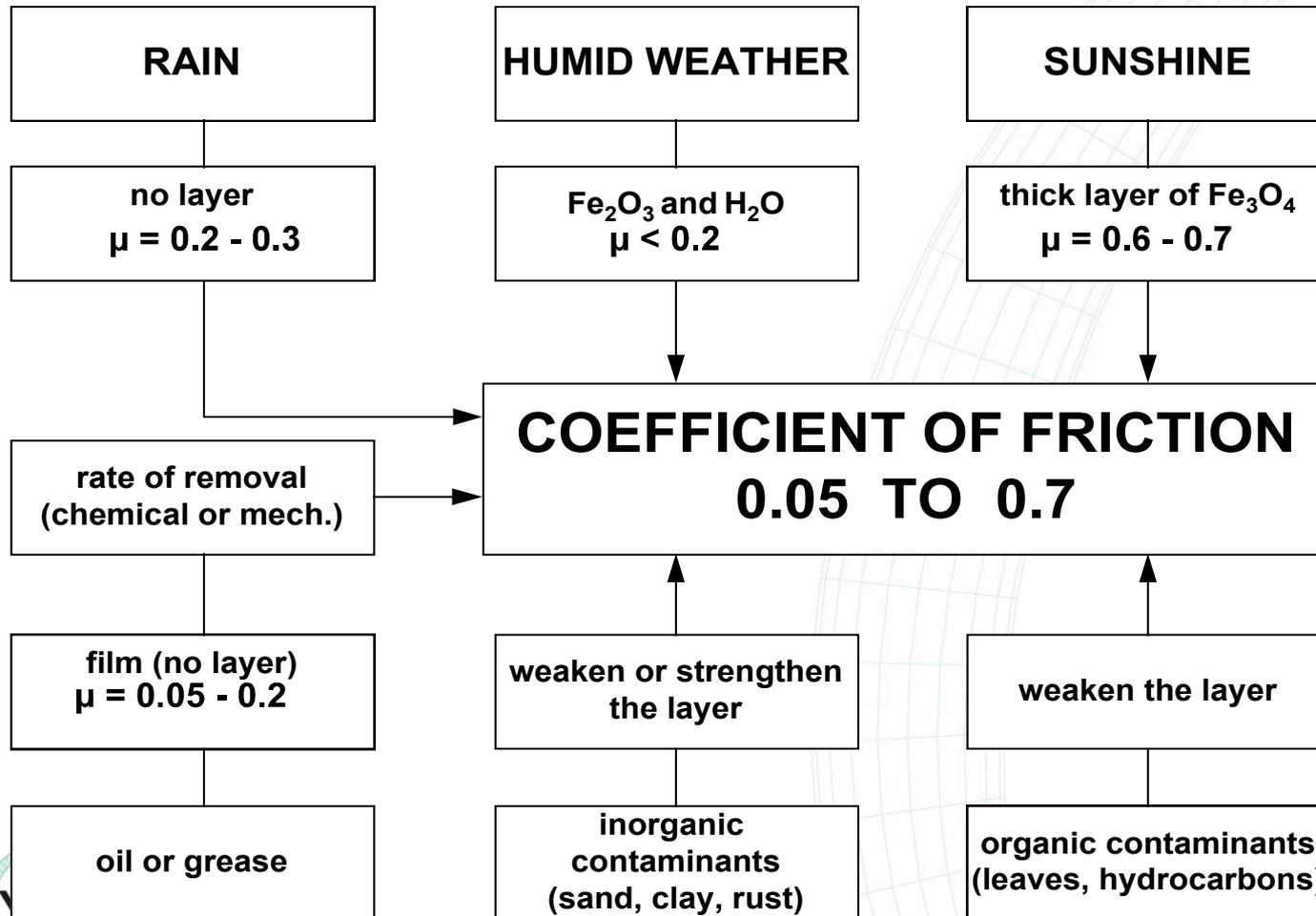


# ICRI – Friction Modeling

Review of past activities & new steps

Edwin Vollebregt  
ICRI WebEx, March 8, 2018.

# Friction is influenced by many factors



What happens  
in each box?

Picture: Kalousek

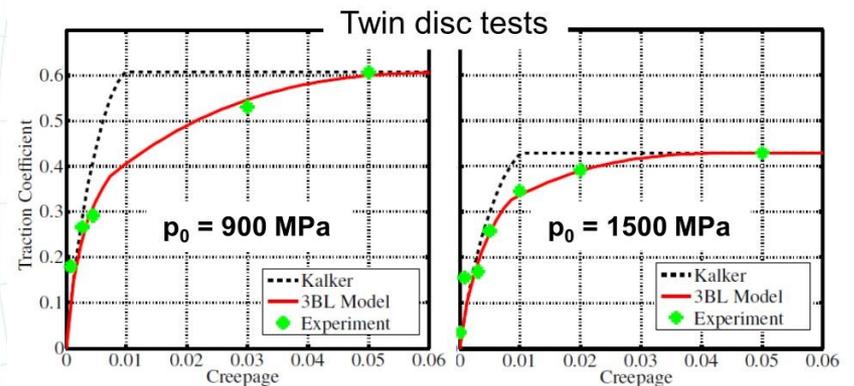
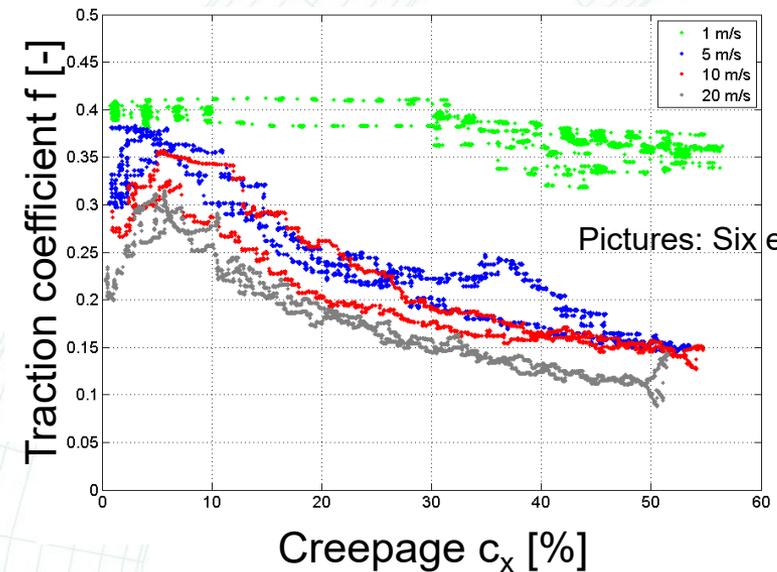
# 2013 – 2014: WebEx discussions

Creep force depends on:

- Creepages
- Vehicle velocity
- Normal load and geometry
- Contact conditions
- Frequency range
- Etc.

**Complex behavior!**

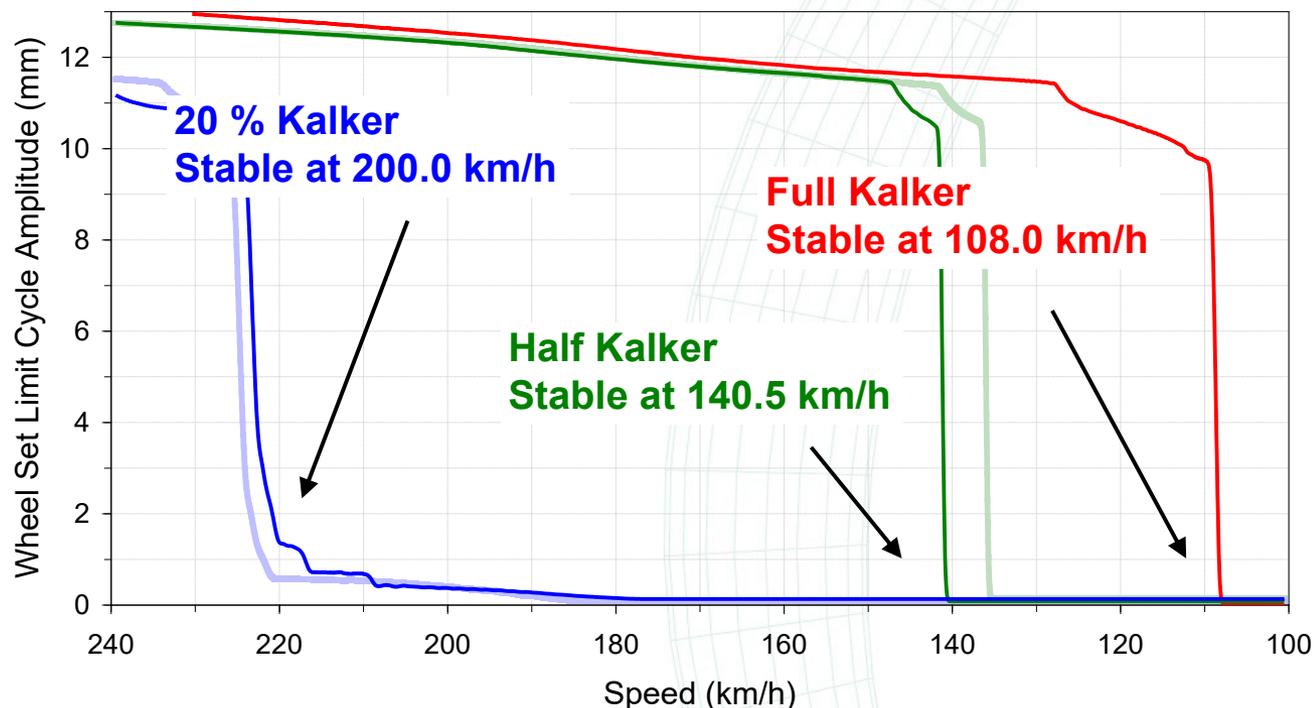
**How to model friction?**



# 2014: Exploring the effects of the creep curve

Implemented Extended CONTACT in VAMPIRE using a table-based approach.

Auto carrier with worn wheel profiles



Picture: Klauser

# 2014 – 2015: Preparation of a project proposal

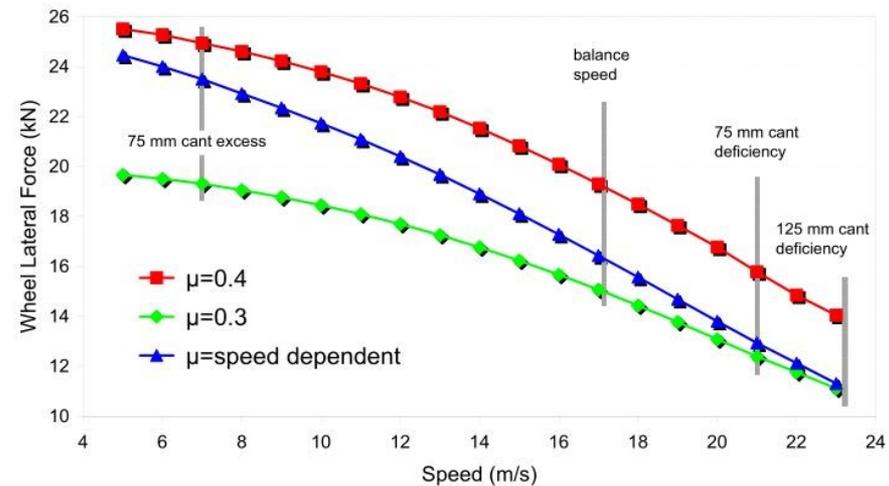
## Improve simulation capabilities

- Fast algorithms;
- In commercial codes;
- With guidance for users.

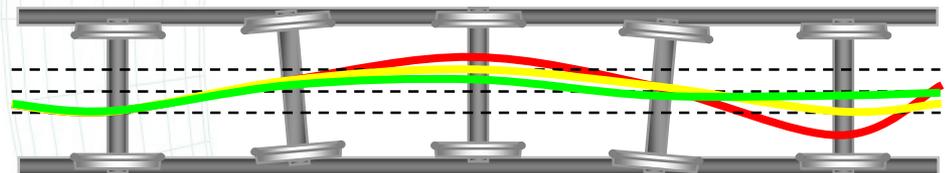
## Advanced modeling & testing

- Effects of friction modifiers
- 3<sup>rd</sup> body layers & fluids
- Speed, load & temperature
- Etc.

Leading Axle Low Rail Wheel Lateral Force for 300 meter Curve



Pictures: Klauser



# 2015 – 2017: Workshop & call for proposals

## FRA workshop

- Best practices on VTI simulation
- Identifying modeling challenges

## “Broad Agency Announcement”

- Call for proposals
- Topic on friction modifiers

## Two projects awarded:

- VORtech: Advanced modeling
- Sheffield & Graz: Advanced testing



U.S. Department  
of Transportation

Federal Railroad  
Administration



**OFFICE OF RESEARCH DEVELOPMENT & TECHNOLOGY**  
FRA OFFICE OF RAILROAD POLICY & DEVELOPMENT



# VORtech: modeling of friction phenomena

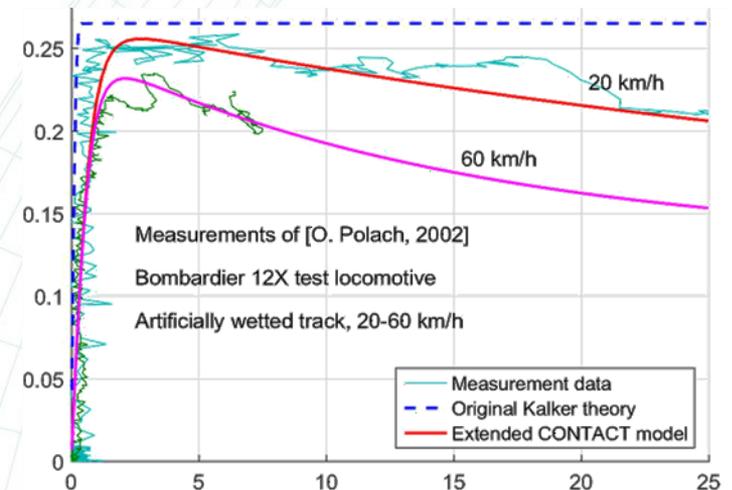
## Project goal:

Improve computer simulation of the influence of:

- friction modifiers, fluids, roughness & temperature

on:

- vehicle stability, curving, derailment, traction control & loads on the track.



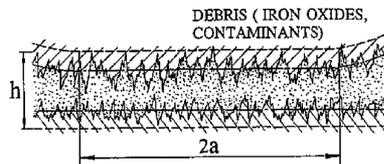
Picture: Marquis

# Advanced modeling of friction phenomena

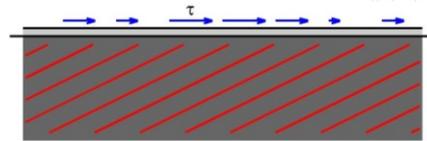
## Project idea:

Estimate the creep forces, accounting for:

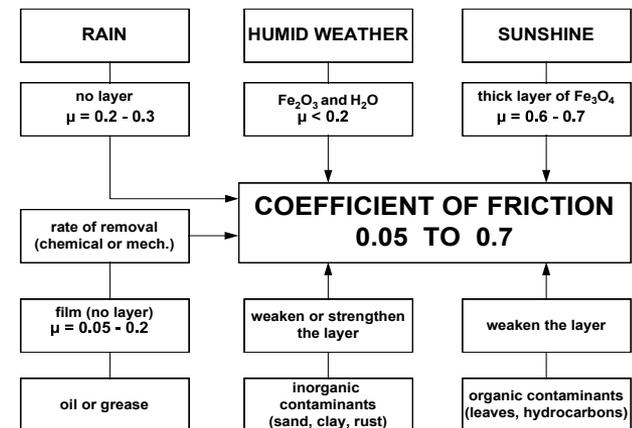
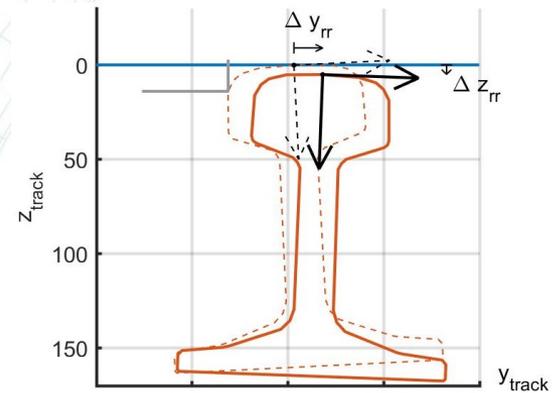
1. Overall wheelset & rail motion
2. Elastic deformation, for given wheel/rail profiles
3. Interfacial layers, fluids, roughness, temperature, plasticity, ...



Picture: Hou et al.



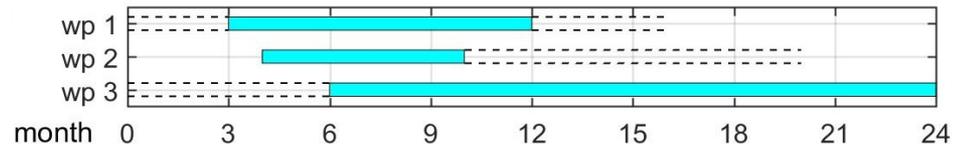
Picture: Kalousek



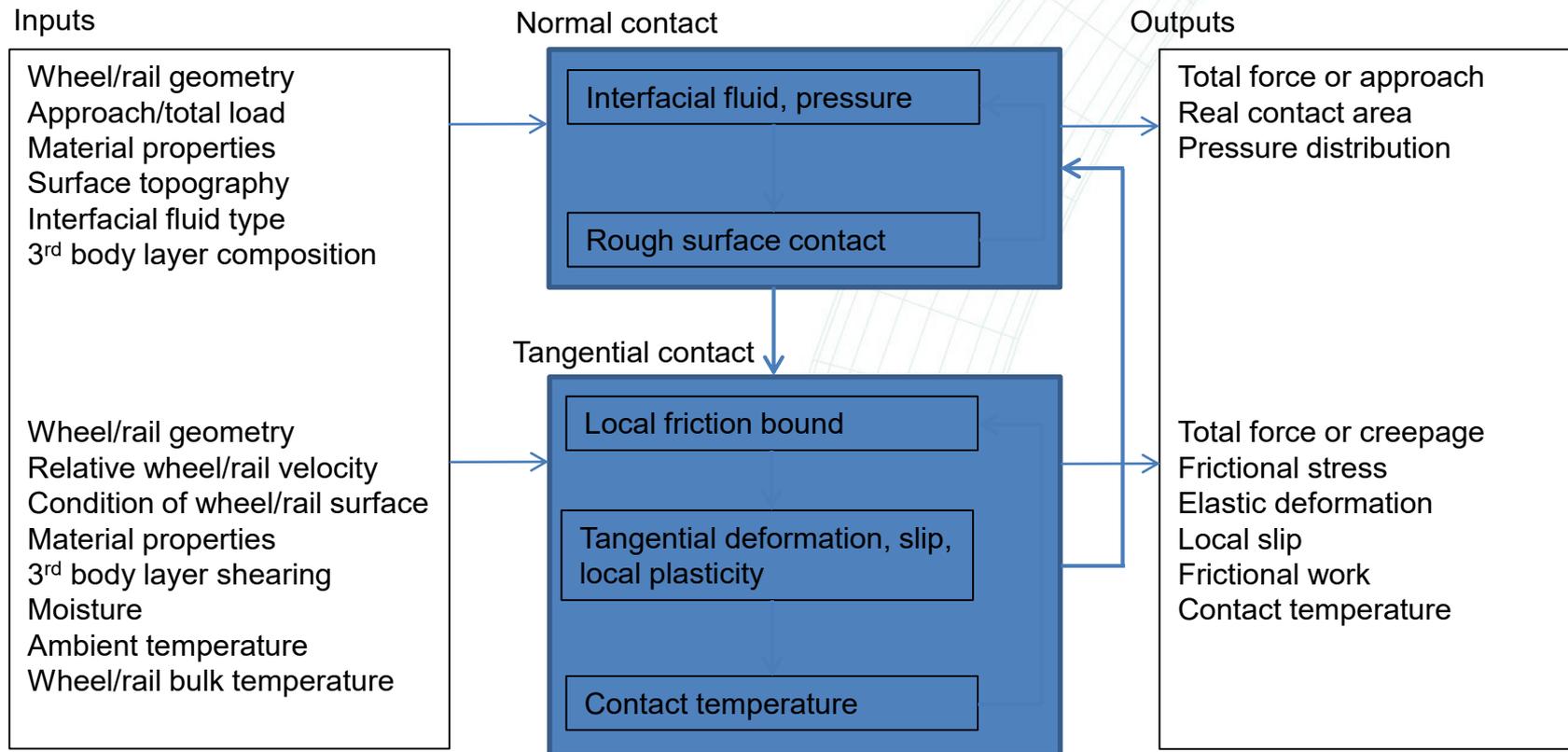
# Advanced modeling of friction phenomena

## Project structure:

- wp3: improve friction modeling in the Extended CONTACT model.  
physics-based sub-models:
  - temperature, roughness, fluids, local plasticity
- wp2: validate against available measurements
  - test-rig data, instrumented wheel-sets?
- wp1: integrate in the main VTI simulation packages
  - GENSYS, NUCARS, SIMPACK, UMECH, VAMPIRE, VI-RAIL



# Wp3: Advanced modeling of friction phenomena

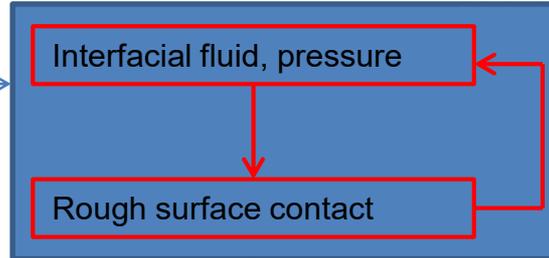


# Wp3: Advanced modeling of friction phenomena

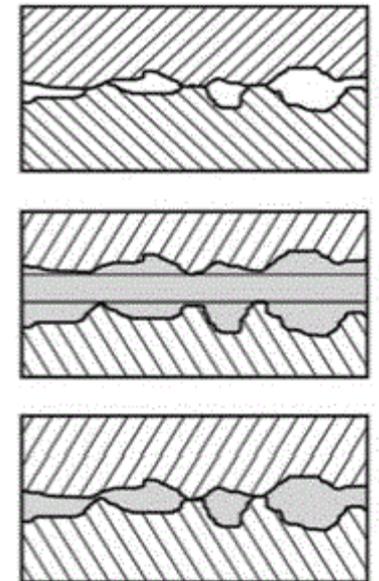
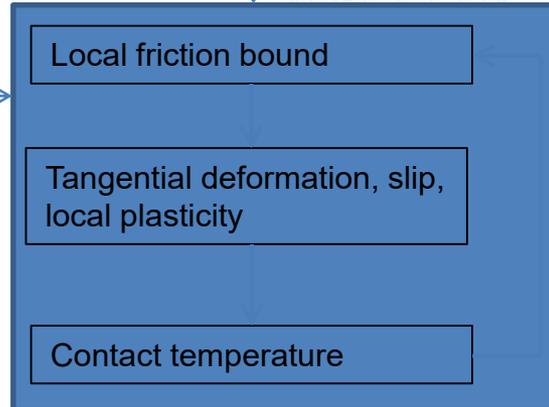
## Inputs

- |   |   |   |
|---|---|---|
| <ul style="list-style-type: none"> <li>Wheel/rail geometry</li> <li>Approach/total load</li> <li>Material properties</li> <li>Surface topography</li> <li>Interfacial fluid type</li> <li>3<sup>rd</sup> body layer composition</li> </ul>  | → | <h3>Normal contact</h3> <ul style="list-style-type: none"> <li>Interfacial fluid, pressure</li> <li>Rough surface contact</li> </ul>  |
| <ul style="list-style-type: none"> <li>Wheel/rail geometry</li> <li>Relative wheel/rail velocity</li> <li>Condition of wheel/rail surface</li> <li>Material properties</li> <li>3<sup>rd</sup> body layer shearing</li> <li>Moisture</li> <li>Ambient temperature</li> <li>Wheel/rail bulk temperature</li> </ul> | → | <h3>Tangential contact</h3> <ul style="list-style-type: none"> <li>Local friction bound</li> <li>Tangential deformation, slip, local plasticity</li> <li>Contact temperature</li> </ul> |

## Normal contact



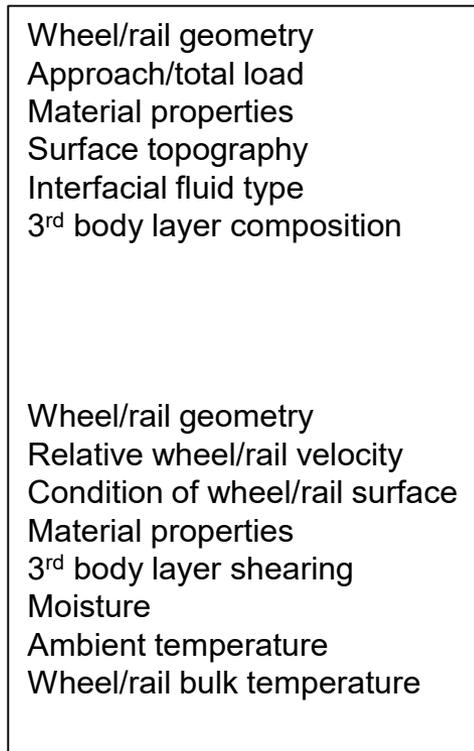
## Tangential contact



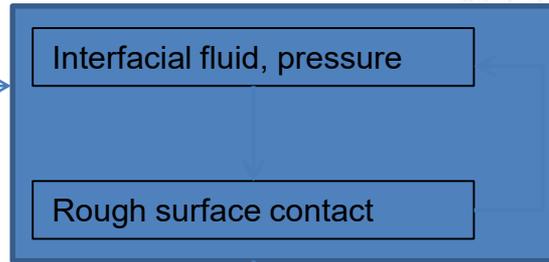
Picture: Neubert

# Wp3: Advanced modeling of friction phenomena

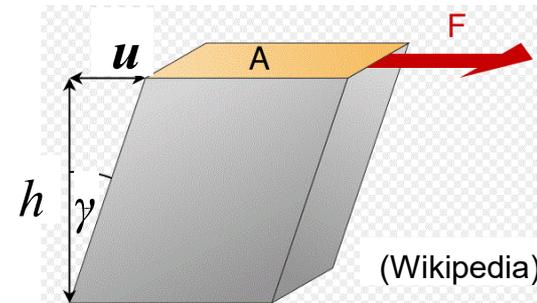
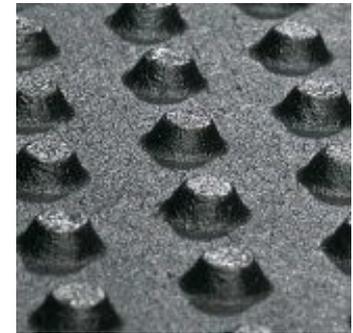
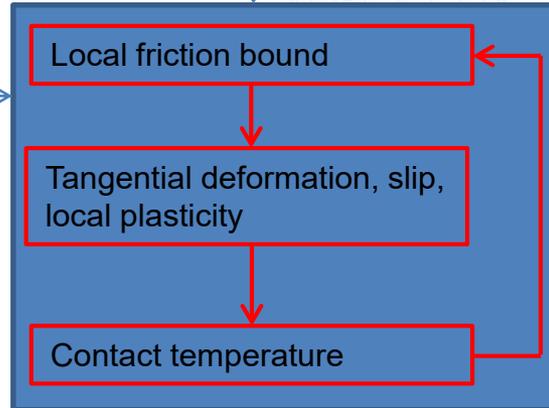
## Inputs



## Normal contact



## Tangential contact



# Wp1: Detailed wheel-rail contact geometry analysis

## Project idea:

Accounting for full, non-Hertzian geometry, including yaw

For wheel-on-rail and wheel-on-roller

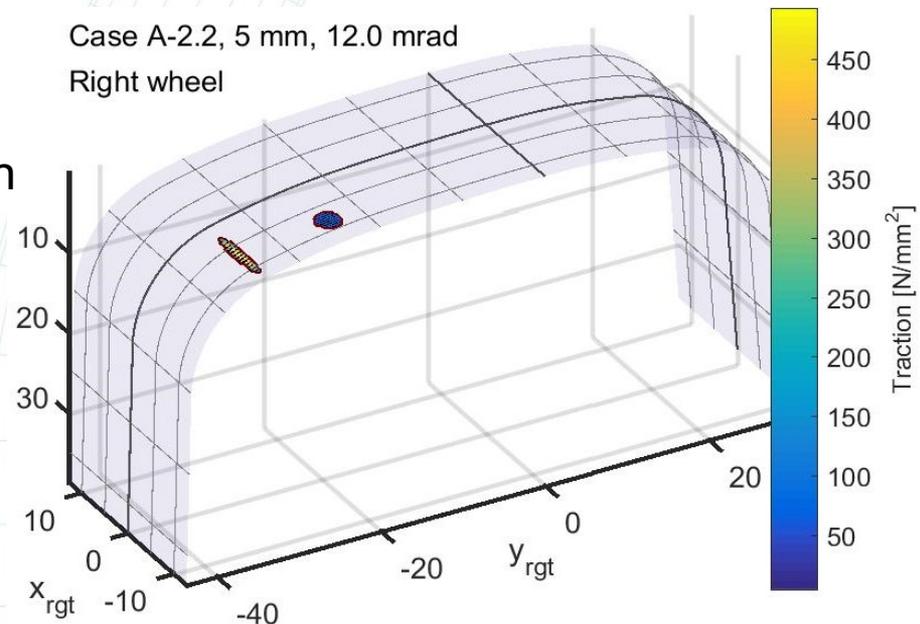
Taking care of contact search,  
undeformed distance & creep calculation

Implemented in stand-alone program  
and CONTACT library

Integrate in main VTI simulation  
packages

Case A-2.2, 5 mm, 12.0 mrad

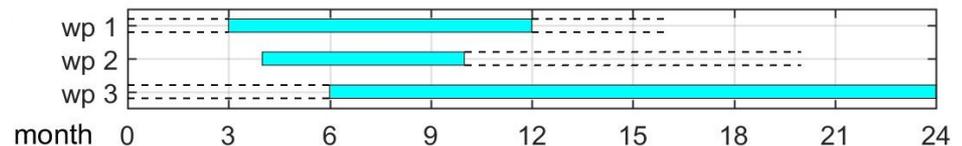
Right wheel



# Advanced modeling of friction phenomena

## Project status:

- wp3: improved friction modeling
  - Temperature implemented for 2D & 3D steady rolling
  - Local plasticity implemented for 2D transient rolling
- wp2: validate against available measurements
  - CONTACT extended for wheel-on-roller configurations
- wp1: integrate in the main VTI simulation packages
  - Underway for GENSYS & UMECH, started for NUCARS

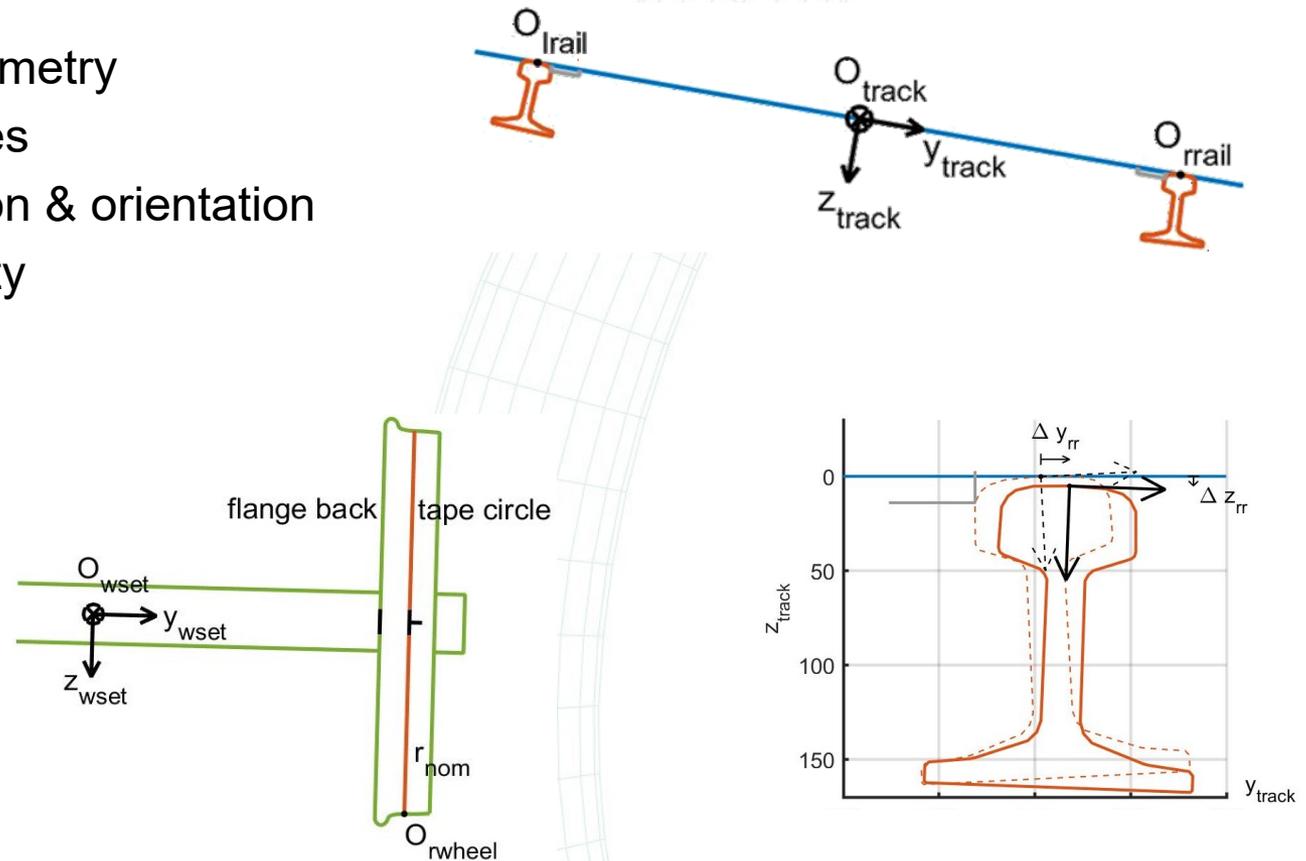




# Wp1: Detailed wheel-rail contact geometry analysis

Accounting for:

- Design track geometry
- Track irregularities
- Wheel-set position & orientation
- Wheel-set velocity
- Actual profiles
- ...



# Detailed wheel-rail contact geometry analysis

```

1 MODULE
0203000      C-P-B-T-N-F-S      CONFIG, PVTIME, BOUND, TANG, NORM, FORCE, STRESS
122033      L-D-C-M-Z-E      FRCLAW, DISCNS, INFLCF, MATER , ZTRACK, EWHEEL
101231      G-I-A-O-W-R      GAUSEI, IESTIM, MATFIL, OUTPUT, FLOW , RETURN
0.280      0.280      82000.  82000.      POISS 1,2,  GG 1,2
0.200      0.200      1.000  1.000      DX, DS, DQREL, SAFETY
1435.0      14.0      0.024995      GAUGWD, GAUGHT, CANT
'MBench_UIC60_v3.prr'  0      RLPROF, MIRRORY
0.0      0.0      0.000      DY, DZ, ROLL
1360.0      -70.0      460.0      FBDIST, FBPOS, NOMRAD
'MBench_S1002_v3.ban'  1      WHPROF, MIRRORY
0.0  6.85  -4.055  -0.0058043  0.0227996  0.0  S, Y, Z, ROLL, YAW, PITCH
40000.  0.01  0.0  0.0  0.0  -86.932  VS,VY,VZ, VROLL,VYAW,VPITCH
    
```

- Specify the overall configuration: left or right wheel/rail or wheel/roller combination

# Detailed wheel-rail contact geometry analysis

```

1 MODULE
0203000      C-P-B-T-N-F-S      CONFIG, PVTIME, BOUND, TANG, NORM, FORCE, STRESS
122033      L-D-C-M-Z-E      FRCLAW, DISCNS, INFLCF, MATER , ZTRACK, EWHEEL
101231      G-I-A-O-W-R      GAUSEI, IESTIM, MATFIL, OUTPUT, FLOW , RETURN
0.280      0.280      82000.  82000.      POISS 1,2,  GG 1,2
0.200      0.200      1.000  1.000      DX, DS, DQREL, SAFETY
1435.0     14.0      0.024995      GAUGWD, GAUGHT, CANT
'MBench_UIC60_v3.prr'  0      RLPROF, MIRRORY
0.0        0.0        0.000      DY, DZ, ROLL
1360.0     -70.0     460.0      FBDIST, FBPOS, NOMRAD
'MBench_S1002_v3.ban'  1      WHPROF, MIRRORY
0.0  6.85  -4.055  -0.0058043  0.0227996  0.0  S, Y, Z, ROLL, YAW, PITCH
40000. 0.01  0.0  0.0  0.0  -86.932  VS,VY,VZ, VROLL,VYAW,VPITCH
    
```

- Specify the rail profile and track geometry

# Detailed wheel-rail contact geometry analysis

```

1 MODULE
0203000      C-P-B-T-N-F-S      CONFIG, PVTIME, BOUND, TANG, NORM, FORCE, STRESS
122033      L-D-C-M-Z-E      FRCLAW, DISCNS, INFLCF, MATER , ZTRACK, EWHEEL
101231      G-I-A-O-W-R      GAUSEI, IESTIM, MATFIL, OUTPUT, FLOW , RETURN
0.280      0.280      82000.      82000.      POISS 1,2, GG 1,2
0.200      0.200      1.000      1.000      DX, DS, DQREL, SAFETY
1435.0      14.0      0.024995      GAUGWD, GAUGHT, CANT
'MBench_UIC60_v3.prr'      0      RLPROF, MIRRORY
0.0      0.0      0.000      DY, DZ, ROLL
1360.0      -70.0      460.0      FBDIST, FBPOS, NOMRAD
'MBench_S1002_v3.ban'      1      WHPROF, MIRRORY
0.0      6.85      -4.055      -0.0058043      0.0227996      0.0      S, Y, Z, ROLL, YAW, PITCH
40000.      0.01      0.0      0.0      0.0      -86.932      VS,VY,VZ, VROLL,VYAW,VPITCH
    
```

- Specify the wheel profile and wheel-set geometry