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Enabling future vehicle technologies

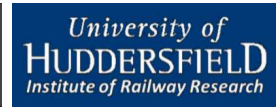


Development of a Modelling Tool for Predicting Wheel/Rail Interface Friction with Leaves

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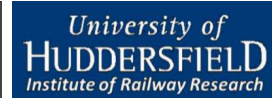
ICRI Webinar 8-10-2020

Overview



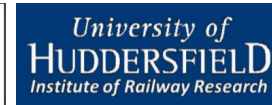
- Background
- Project aims and overview
- HAROLD test set-up and low adhesion test methodologies
- Summary of HAROLD results – dry, wet, leaves, paper tape and soap
- Friction modelling
- Model application
- Possible future work

Overview



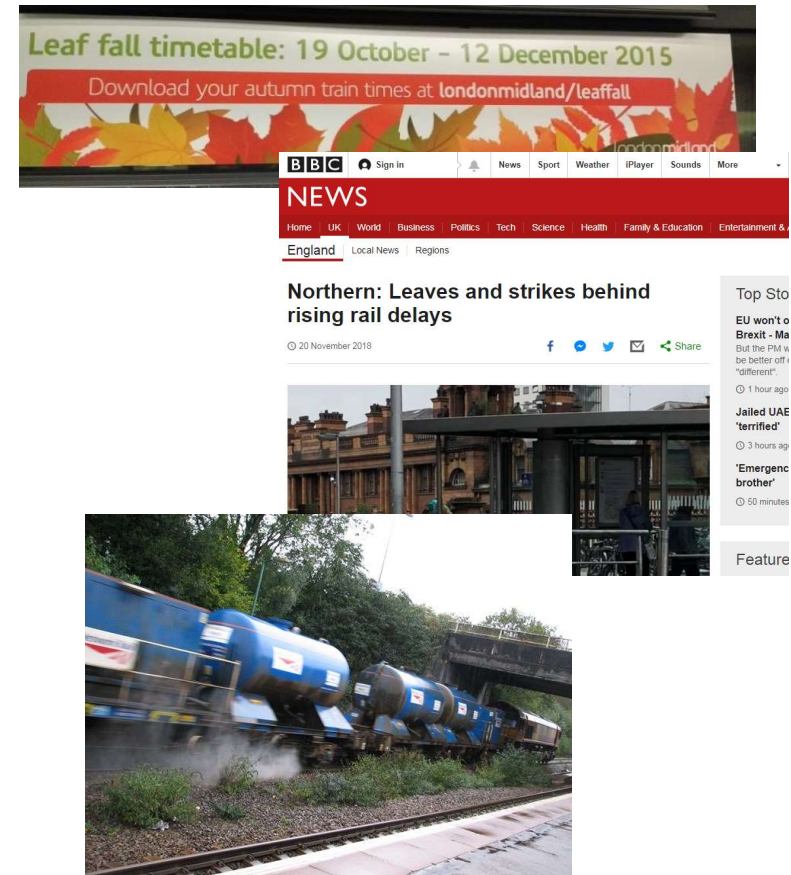
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Background



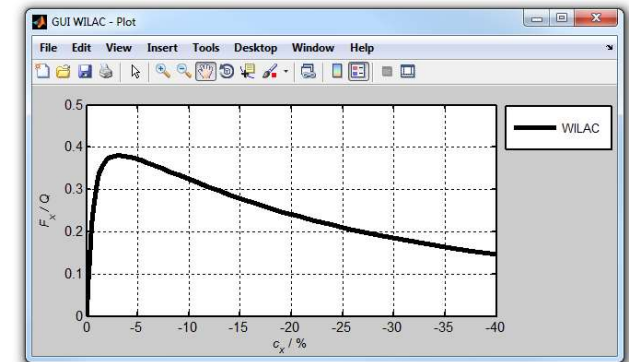
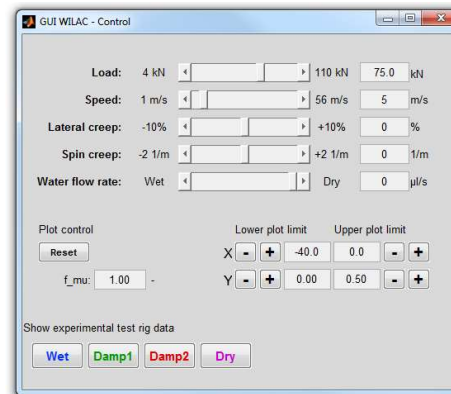
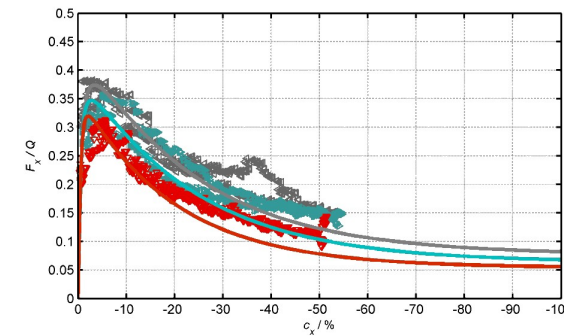
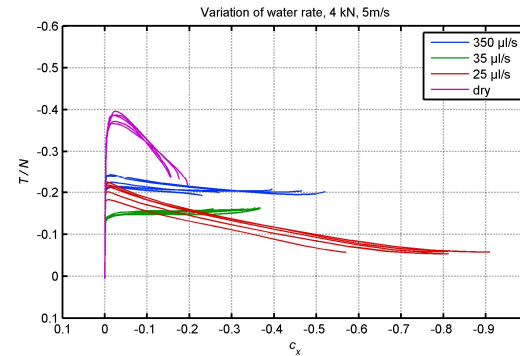
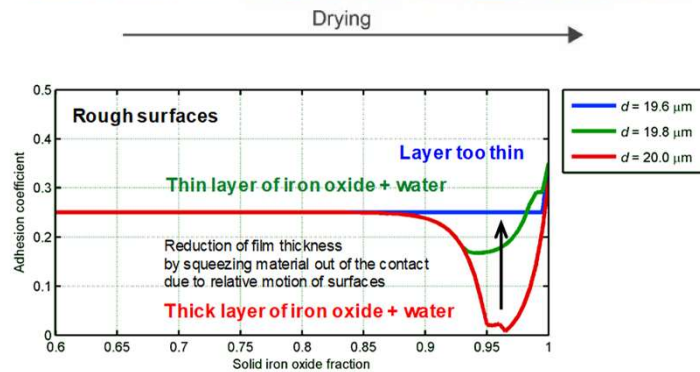
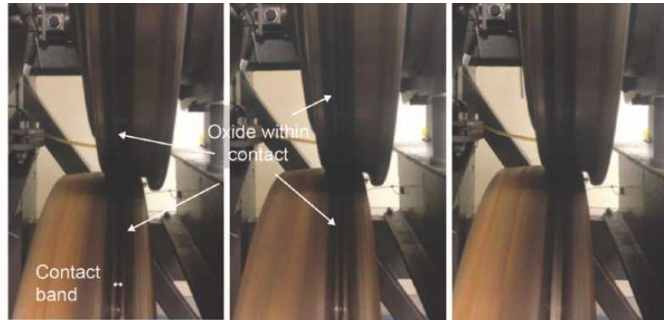
Low Adhesion:

- Mainly caused by leaves and “wet-rail” – can happen all year round
- Safety – poor braking leads to SPADs and station overruns
- Performance – lower traction causes delays and customer dissatisfaction
- Cost of low adhesion is around £350m per year in the UK alone, including:
 - costs of rail head treatment via specialist trains (water jetting and traction gel) and wayside application of traction enhancer
 - wheel and rail maintenance
 - delay minutes



WILAC Model

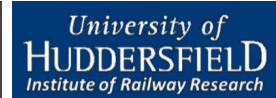
- Water Induced Low Adhesion Cree force model (WILAC) developed for „wet-rail“
- Implemented in LABRADOR train braking model
- Needed expanding to other causes of low adhesion



Key references:

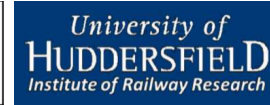
- Buckley-Johnstone et al., 2020, *Tribology International*, 141, 105907.
- Buckley-Johnstone et al., 2019, *Tribology International*, 135, pp55-64.
- Trummer et al., 2017, *Tribology International*, 109, 409-415.
- Alturbeh et al., 2020, in press, *Tribology – Materials, Surfaces and Interfaces*.

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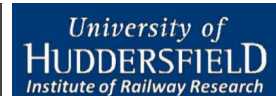
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Project Aims



- **The aim of project T1149** was to extend the friction model (WILAC) developed in project T1077 to predict the effects of small amounts of water, to incorporate the impact of leaf layers
- **Full-scale tests** were planned on the University of Huddersfield's HAROLD rig to provide model input data. This extended the testing capability a long way beyond the rig used in T1077 in terms of speed and load application

Project Overview



WP1 – Data collection

- Review low adhesion causes – incident reports, academic papers, stakeholder engagement
- Review T1077 GB: low adhesion scenarios, operating and environmental conditions



selection of low adhesion mechanisms and operational scenarios



WP2 – Tribological testing and modelling

- HPT/twin disc/full-scale
- Adhesion modelling
- Variables:
 - low adhesion “material”, amount, application method
 - contact load, slip ratio, specimen roughness, etc.



low adhesion mechanisms and inputs to model



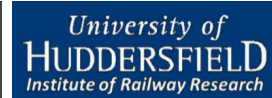
WP3 – Extend WILAC

- Model adaption for new low adhesion mechanisms
- Parameterization



Updated model source code ready to implement in LABRADOR e.g. MATLAB code

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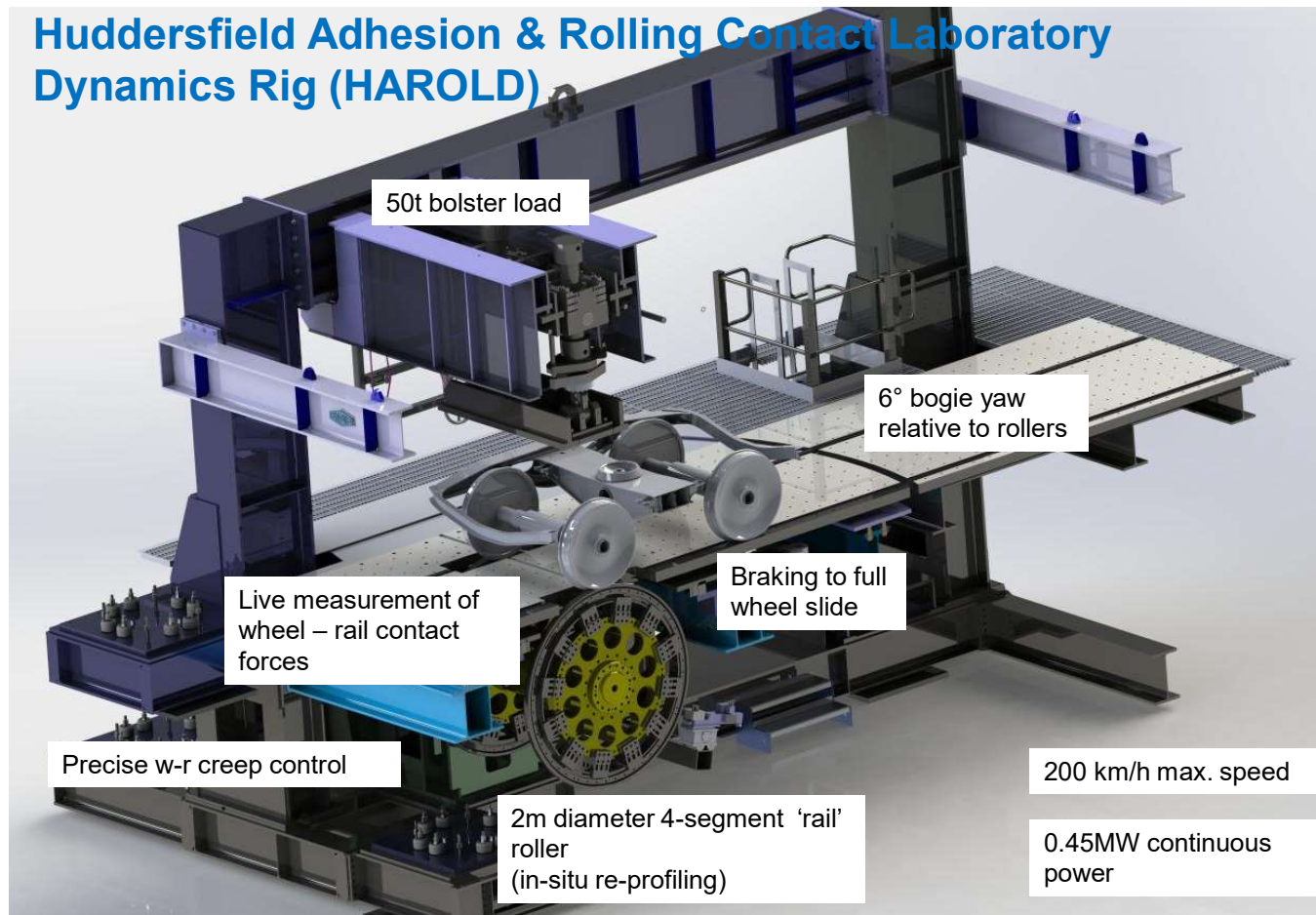
HAROLD Test Set-up



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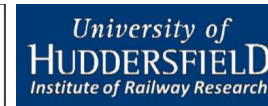
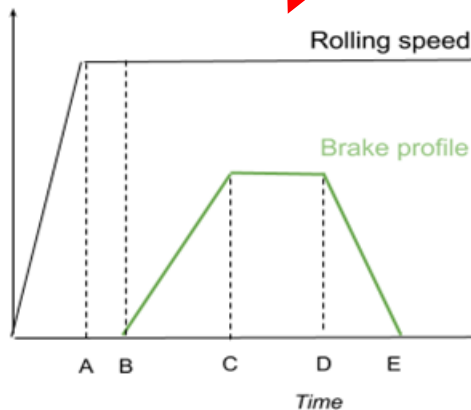


Huddersfield Adhesion & Rolling Contact Laboratory Dynamics Rig (HAROLD)



HAROLD Test Set-up

- The rig consists of a Y25 freight bogie positioned with front wheelset on a 2m diameter rolling rail
- The bogie has tread brakes, so one side was jacked up used for braking while the other side had contaminant applied and
- Brake force is gradually increased until a limit is reached or “WSP” activation vents the pneumatic actuator

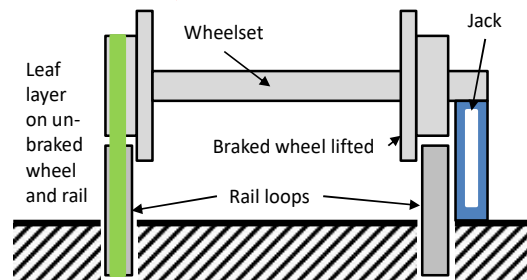


Manual control board



Rotary encoder

Wheel/rail contact



Load actuators

Brake actuator

Longitudinal load cells

Test Methodologies

The standard test procedure for a test is as follows:

1. Test rig brought up to specified load and velocity
2. Incremental increase of brake force until wheel slide or maximum brake force application
 - a) If set creepage level is exceeded, then braking stops and free rolling is allowed to resume
3. Roller decelerates to zero velocity
4. End of test

To create a leaf layer:

- Rig is slowly rotated using the manual control procedure on HAROLD whilst leaves are fed into the contact
- The roller is then rotated whilst a normal load is applied to 'bed' the leaves into the surfaces
- A black leaf film is only visible after the leaf film has undergone a sliding event
- Leaf layer was wetted before test method above was used

Tests were run in dry and wet conditions and with leaves, paper tape and soap. Here only dry and leaf layer data are shown



Leaf film pre-test

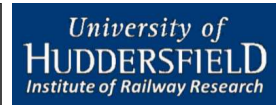
Leaf film post 1 test

Remaining leaf film post 3 tests

Leaf Layer Creation



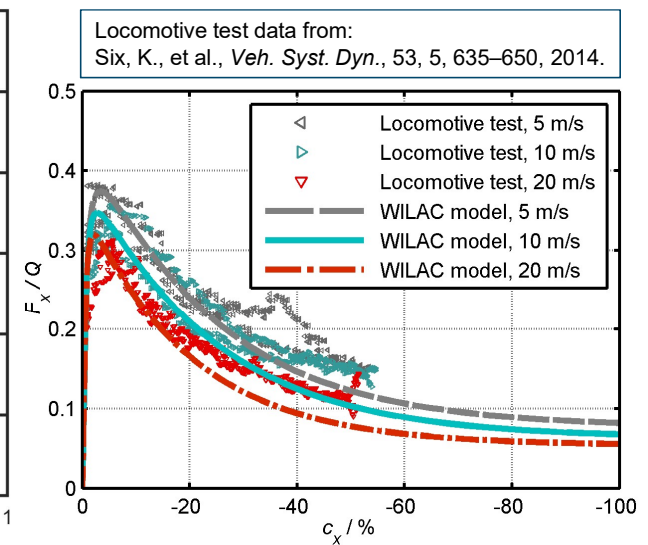
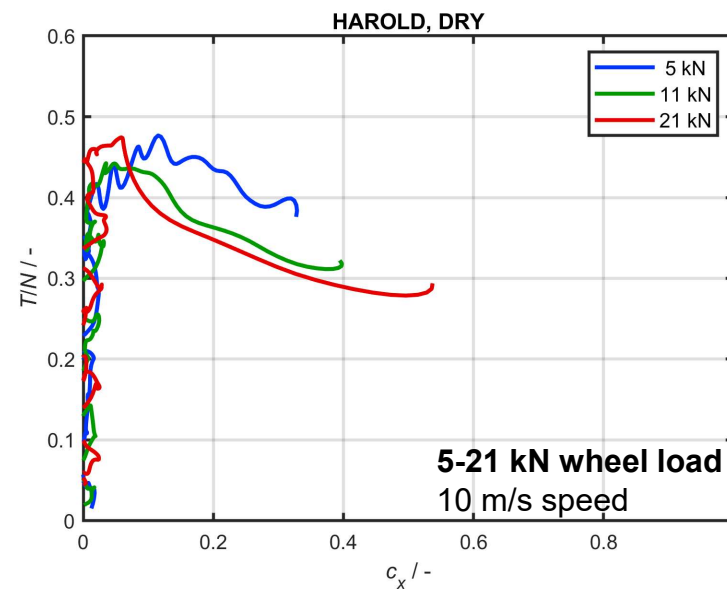
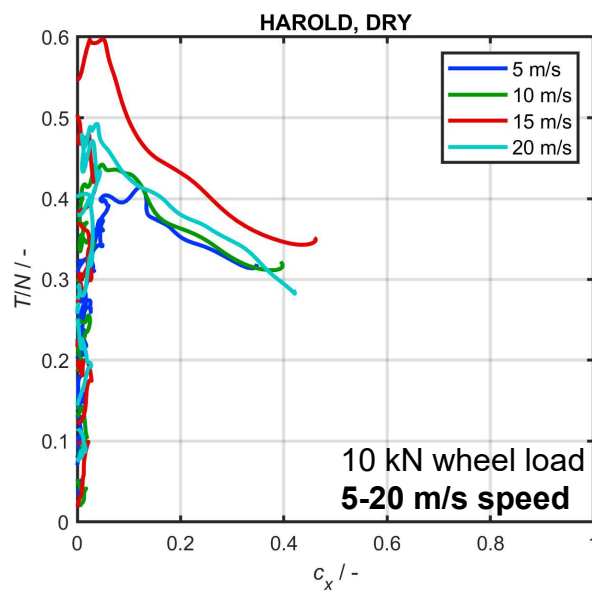
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Summary of HAROLD Results

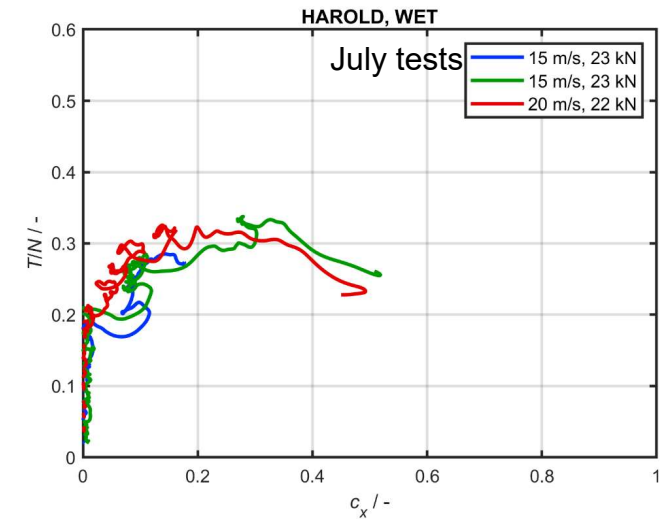
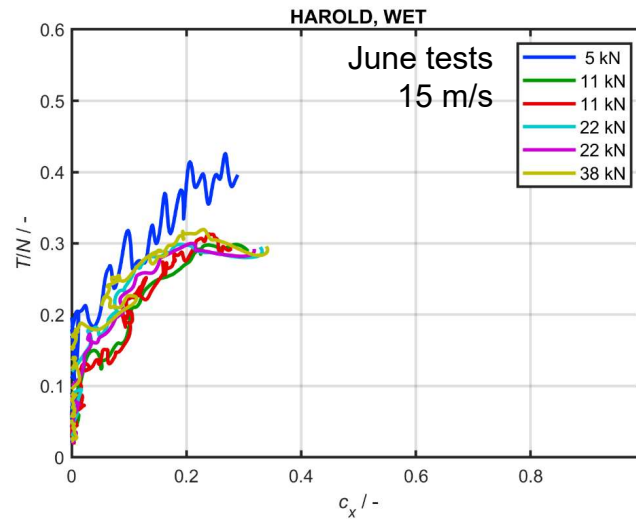
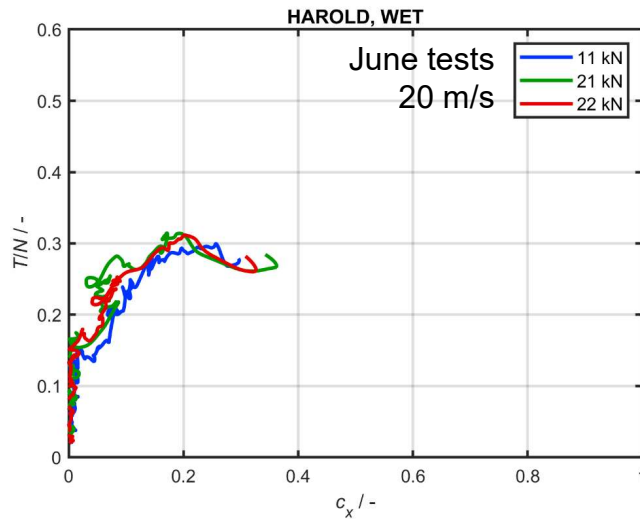
Dry



- Data same shape, but higher than locomotive tests
- Thicker 3rd body layers of oxide and wear debris build-up in cyclic tests which would explain this difference

Summary of HAROLD results

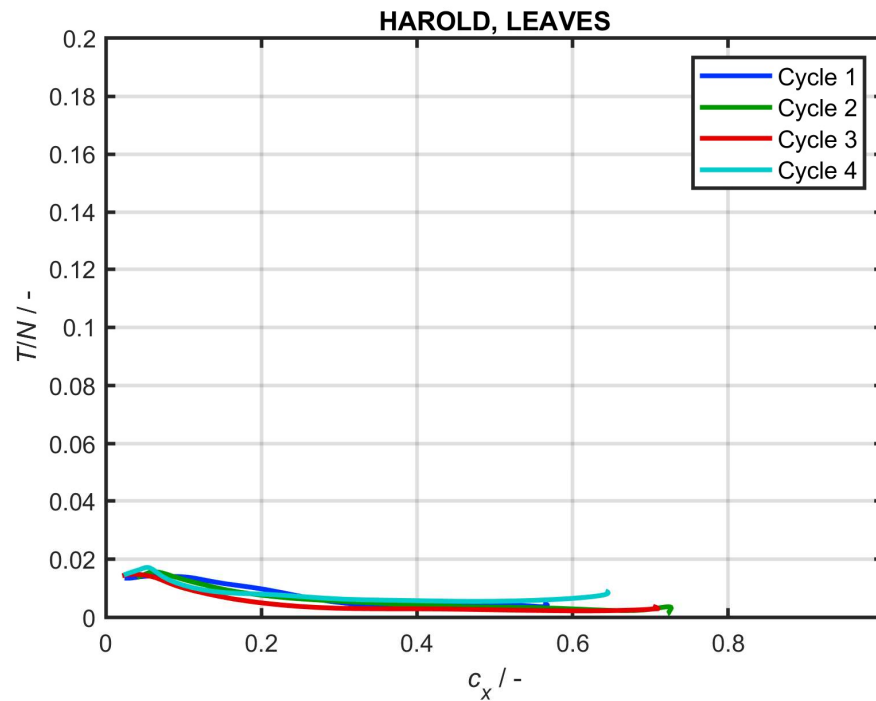
Water, 15 m/s – 20 m/s



- Adhesion at the onset of sliding: 0.15 – 0.21
- Increase of adhesion during sliding event with peak at 0.30
- Falling adhesion for $c_x > 0.2$

Summary of HAROLD Results

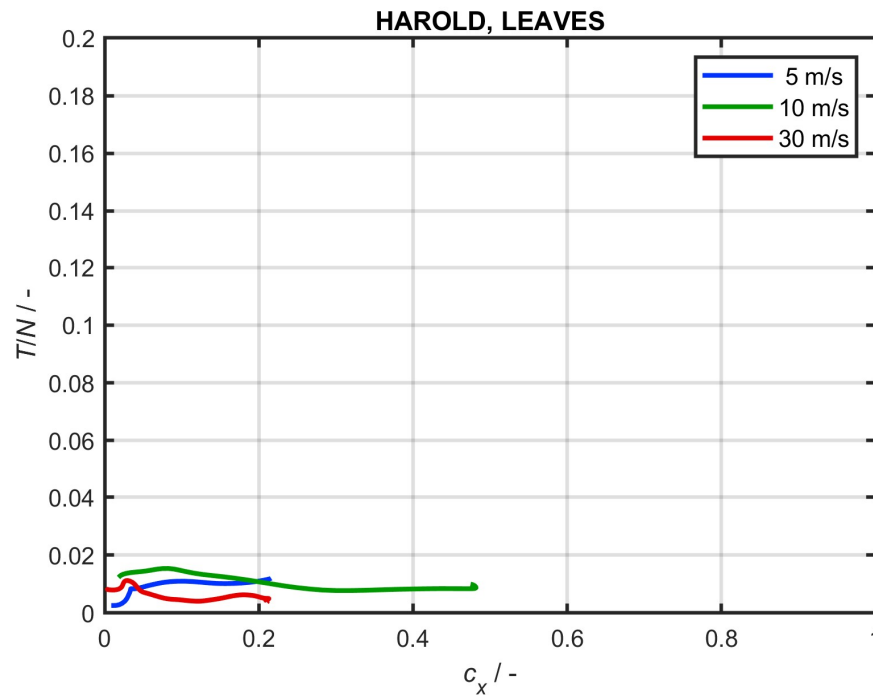
Leaves: 100 kN, 10 m/s, 4 consecutive cycles



- Adhesion ≈ 0.01 over large range of creep
- **Good repeatability** of adhesion values at high wheel loads within one test series

Summary of HAROLD Results

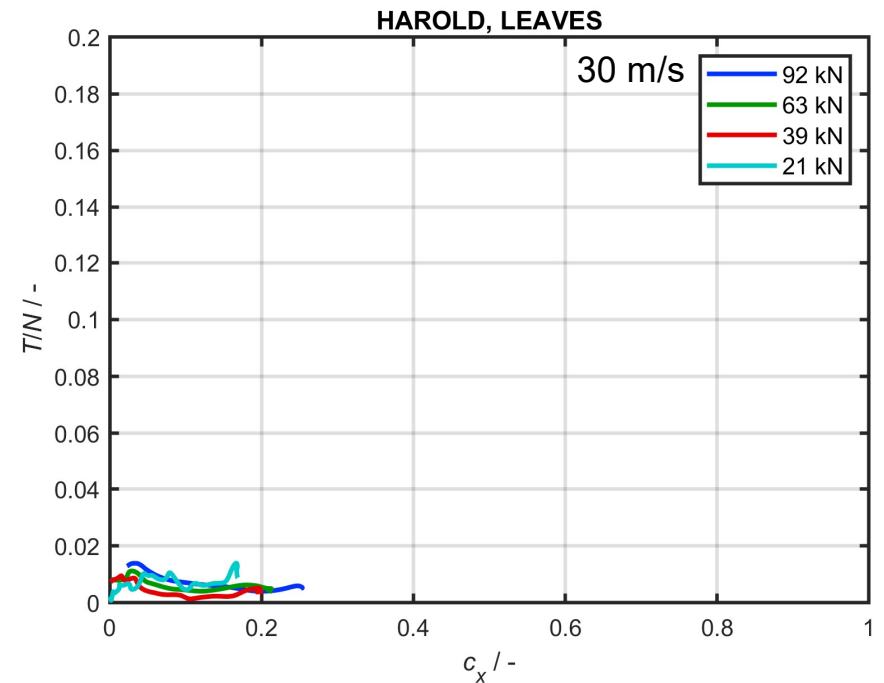
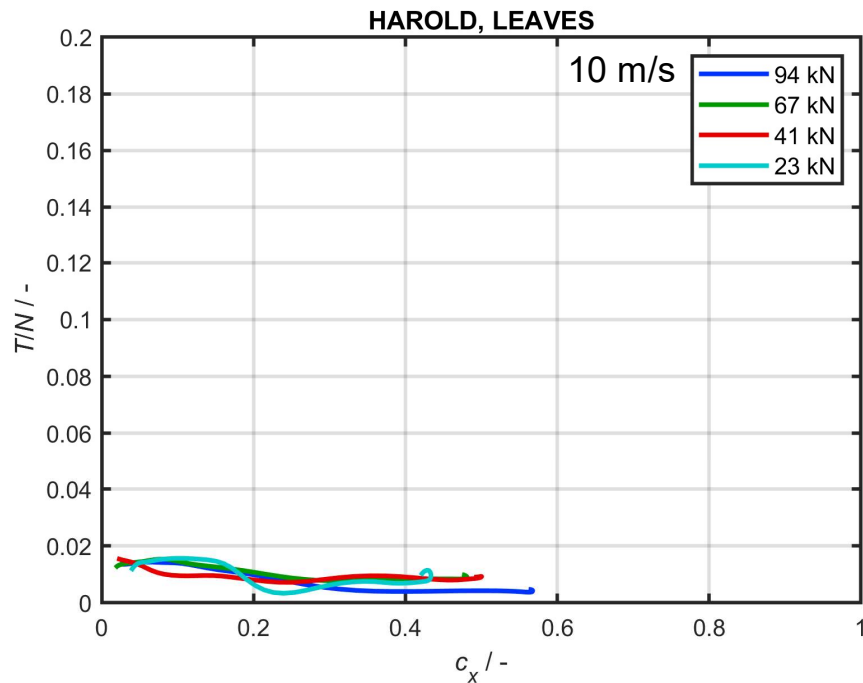
Leaves: 60 kN, influence of rolling speed



- Slight decrease in adhesion values with increasing speed

Summary of HAROLD Results

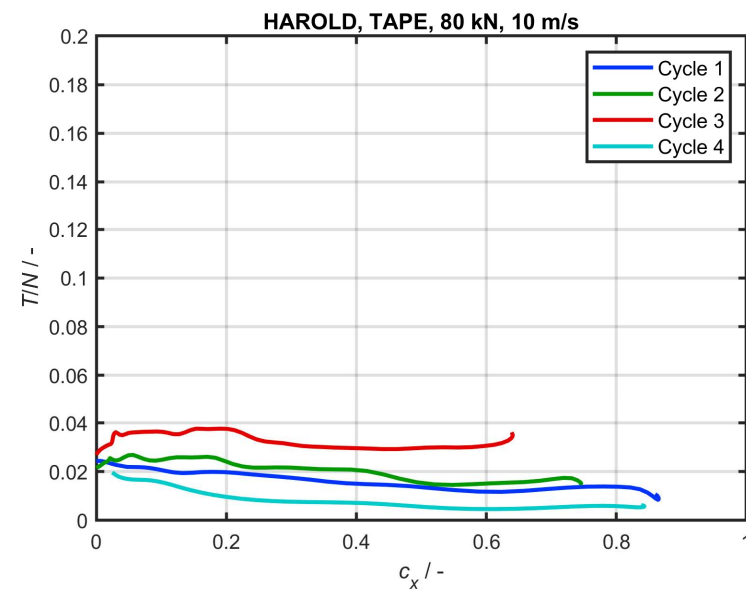
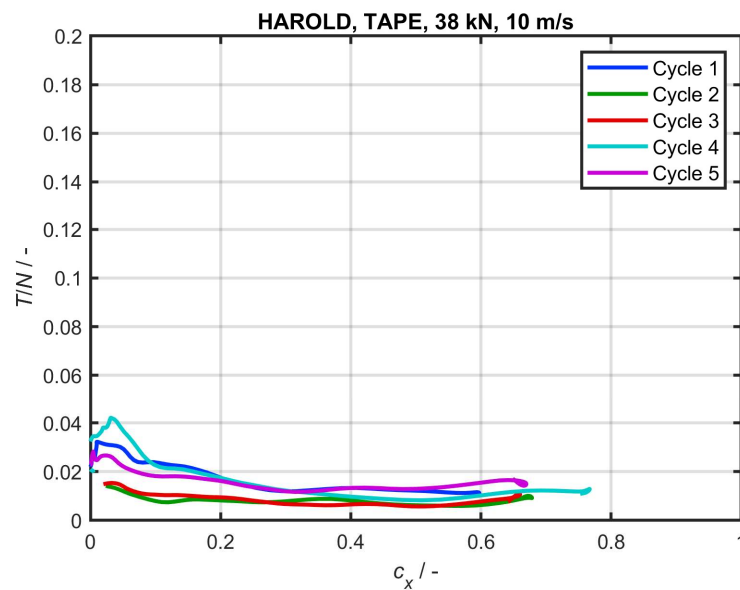
Leaves: Influence of wheel load



- No influence of wheel load on adhesion level observed at 10 m/s and 30 m/s

Summary of HAROLD results

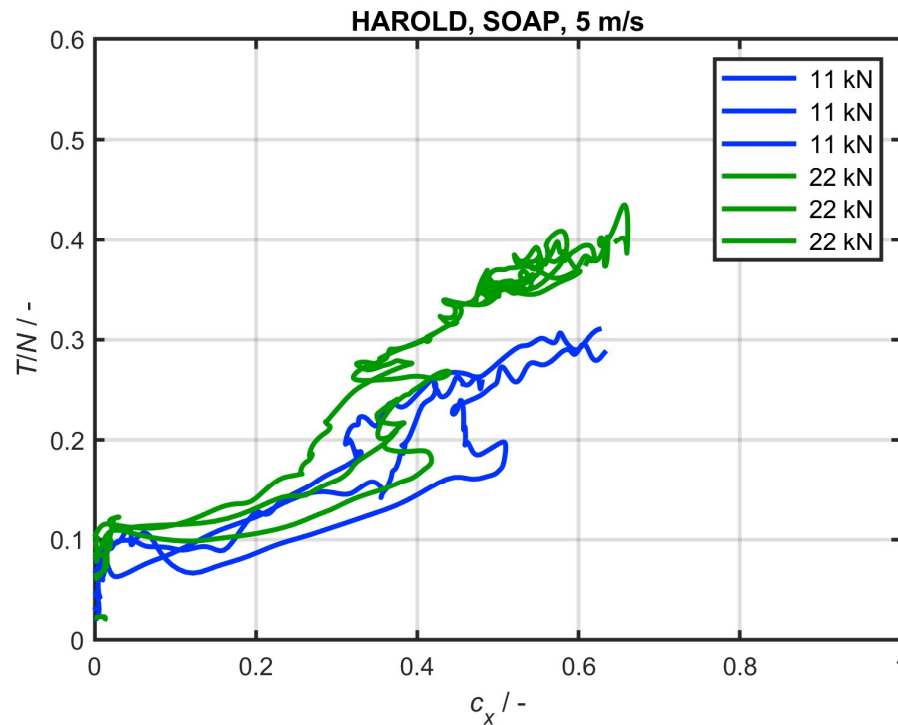
Tape & Water, 10 m/s



- Similar minimum adhesion levels as with leaves
- Minimum adhesion level independent of wheel load

Summary of HAROLD results

Soap & Water: 5 m/s



- Adhesion 0.10 at the onset of sliding, followed by adhesion recovery during sliding event up to 0.40
- Faster adhesion recovery for higher loads

Summary of HAROLD Results



Summary

- Experimental testing at HAROLD rig successfully carried out in June/July 2019
- Investigated conditions:
 - Dry
 - Water
 - Leaves
- Some additional experiments with:
 - Soap & Water
 - Tape & Water
- Dry data generated comparable with T1077 results and locomotive data from literature
- **Low adhesion ≈ 0.01 achieved with leaf layer for multiple braking events for wheel loads up to 100 kN**

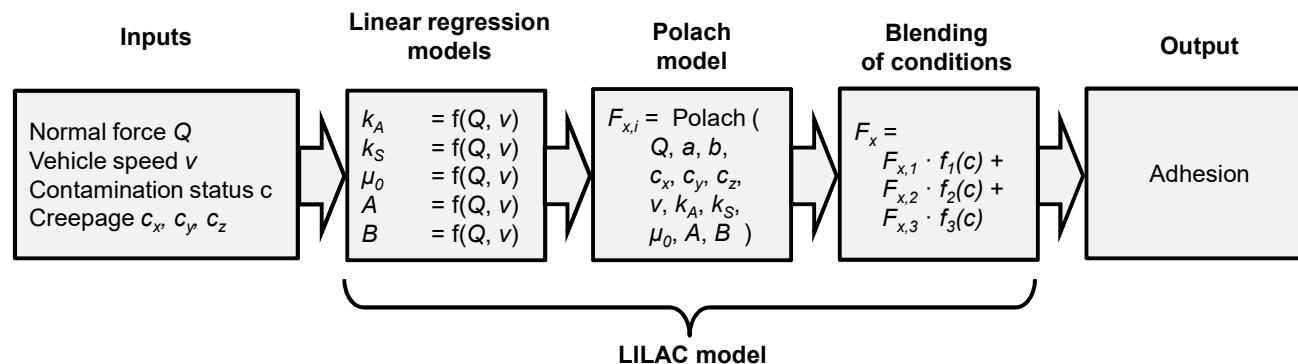
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LILAC model parameterization methodology

- Fit ECF [1] model to experimental results
- Reproduce ECF model results with a Polach model approach [2,3]
 - Fit individual Polach creep force curves to individual ECF creep force curves
→ Sets of Polach parameter for ECF curves
 - Create linear regression models for Polach parameters k_A , k_S , μ_0 , A , B as a function of wheel load Q and rolling speed v



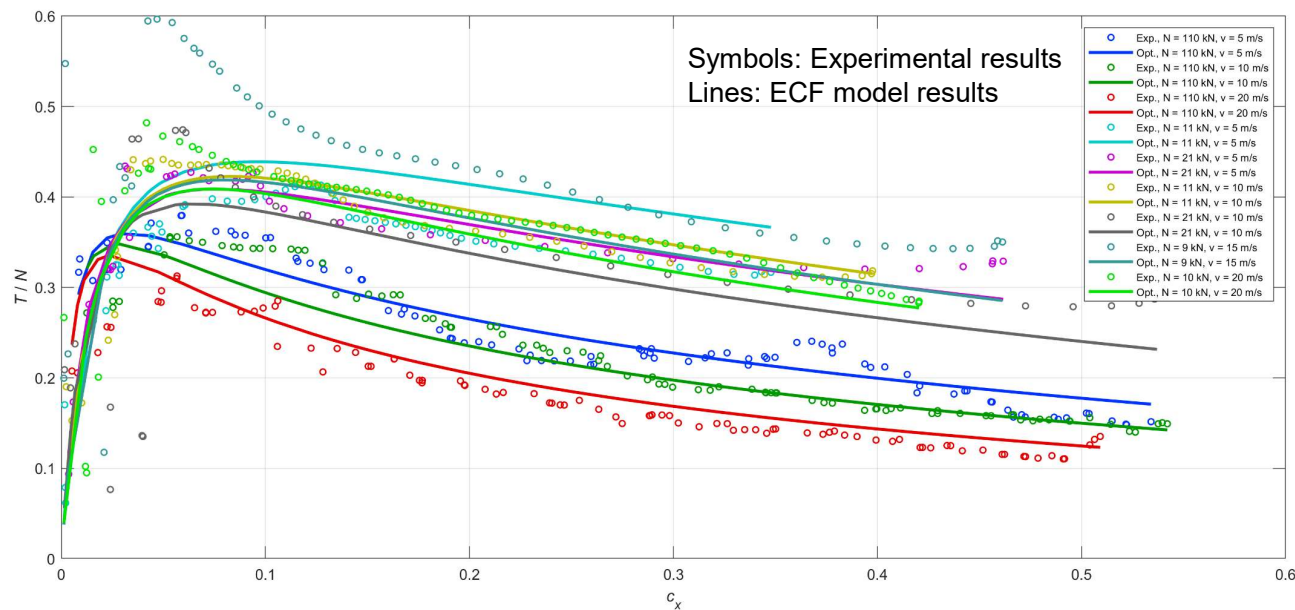
[1] A. Meierhofer, A new Wheel-Rail Creep Force Model based on Elasto-Plastic Third Body Layers, *Graz University of Technology*, **2015**.

[2] O. Polach, A fast wheel-rail forces calculation computer code, *Proc. of the 16th IAVSD Symposium, Pretoria, August 1999, Vehicle System Dynamics Supplement*, **1999**, 33, 728-739.

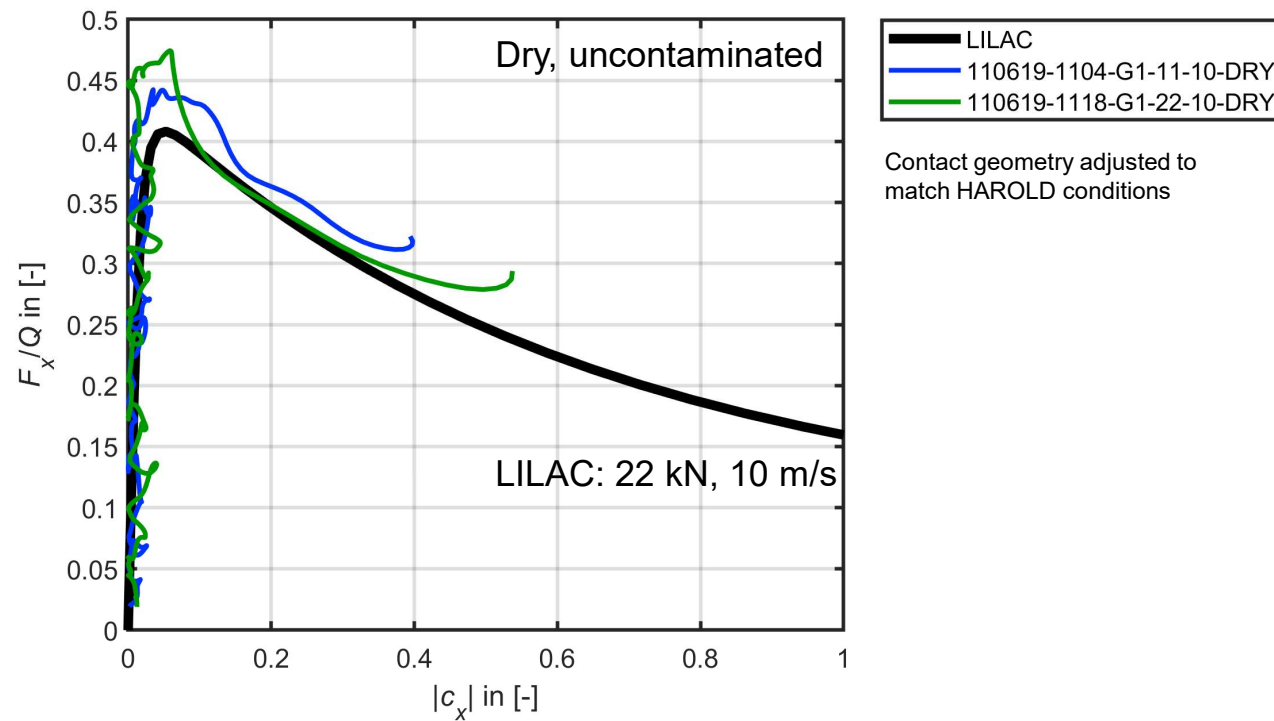
[3] O. Polach, Creep forces in simulations of traction vehicles running on adhesion limit, *Wear, Elsevier*, **2005**, 258, 992-1000, .

Model parameterization: Dry contact condition

- Intermediate stage for parameterization process:
 - ECF model (lines) fitted to experimental data (from HAROLD tests and other sources, such as locomotive data) using an iterative process to tune across a range of key parameters (load, speed, slip in the contact, etc.)

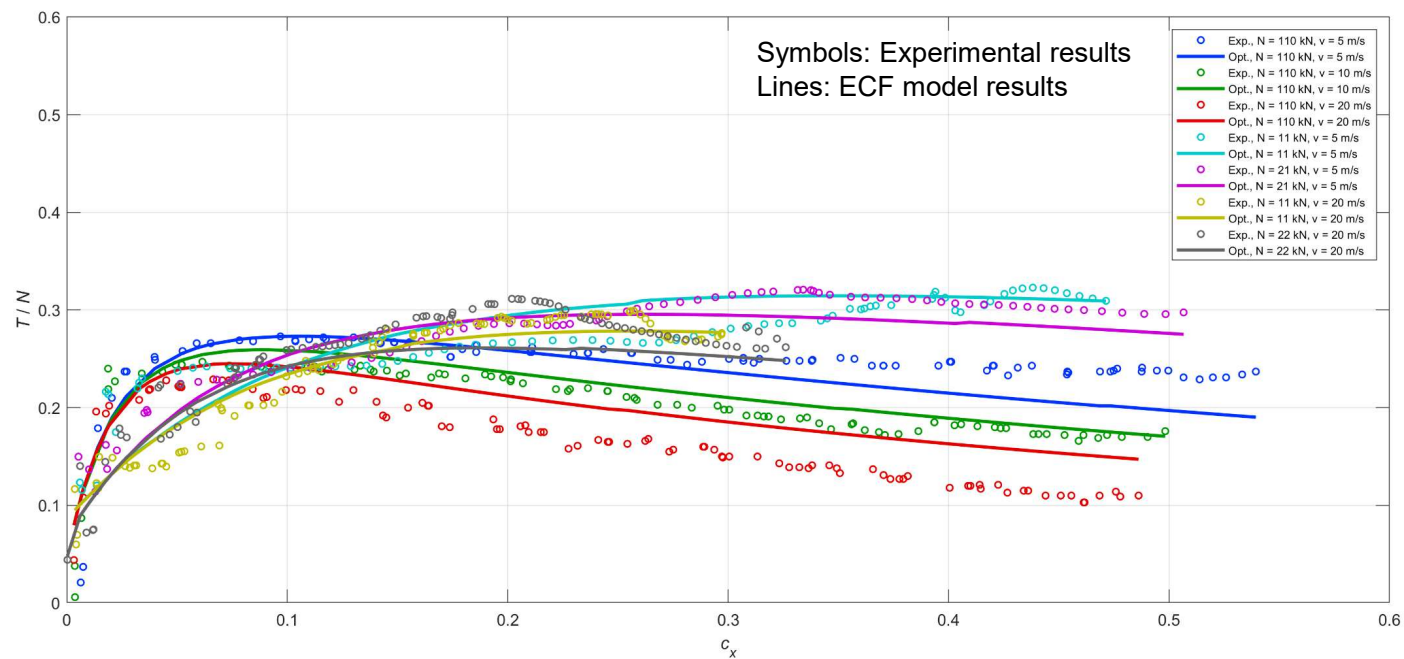


Check of parameterization: Dry contact: LILAC modeling results & HAROLD experimental results

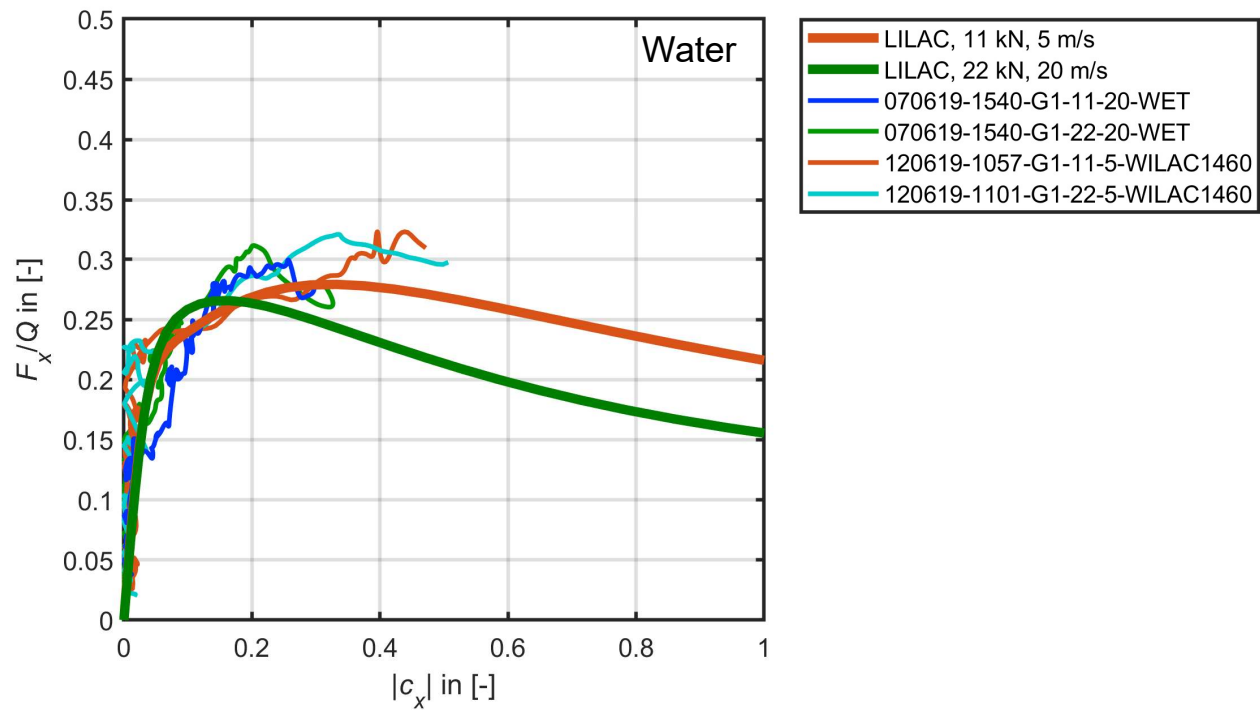


Model parameterization: Wet contact condition

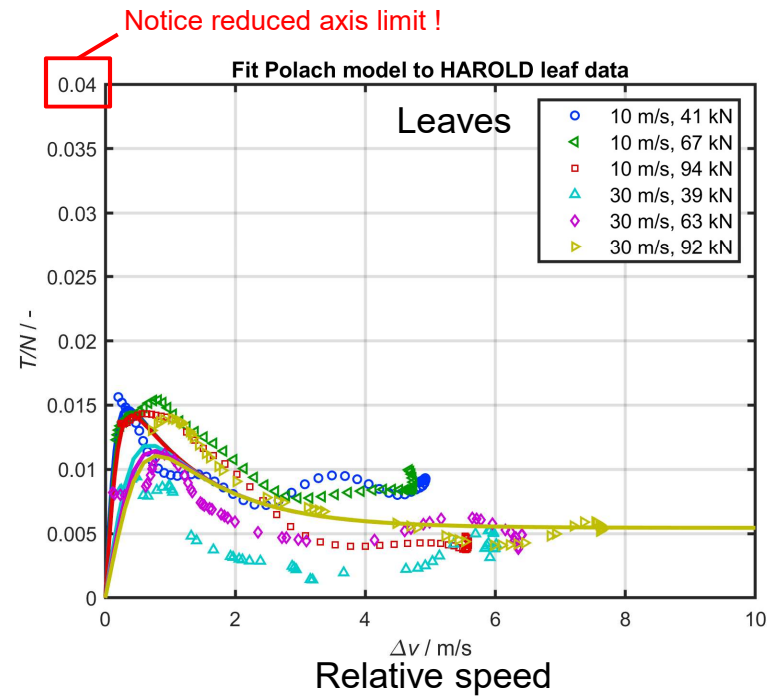
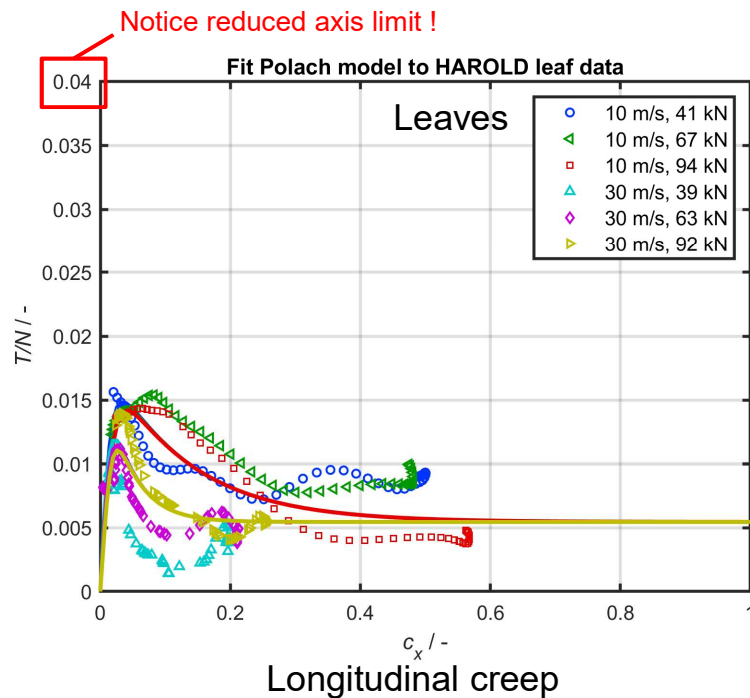
- Intermediate stage for parameterization process:
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Check of parameterization: Wet contact: LILAC modeling results & HAROLD experimental results



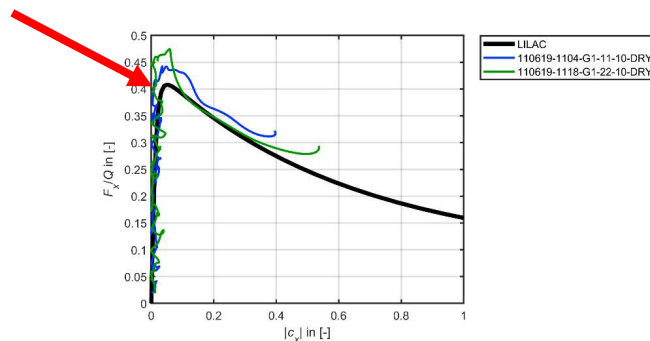
Line fitting for leaves



- Experimental data are well reproduced by Polach model with fixed parameters

Updated LILAC Graphical User Interface (GUI)

- Option to select contamination type / scenario
 - Leaves
 - Water: HAROLD stable operating conditions
- Slider to specify extent of contamination
- Output is a creep curve (friction coefficient vs creepage)



RSSB T1149 - GUI LILAC v1.0 - Control

Normal force: 4 kN 110 kN 50 kN

Vehicle speed: 1 m/s 56 m/s 5.0 m/s

Lateral creep: -10% +10% 0.0 %

Spin creep: -2 1/m +2 1/m 0.0 1/m

Contamination type: ☒ Water ☐ Leaves ☐ WILAC

Contamination status: None Full 0

Plot control

Reset

f_mu: 1.00

Exp. data:

Lower plot limit Upper plot limit

X - + 0.000 1.000 - +

Y - + 0.00 0.50 - +

RSSB The University Of Sheffield. University of HUDDERSFIELD virtual vehicle

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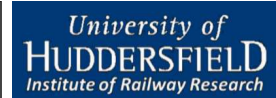
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- **The new HAROLD test capability could be used to:**
 - Assess new friction control technologies within the wheel/rail interface
 - Study the performance of new brake designs in low adhesion conditions

- **The model would suit a variety of applications:**
 - Integration into the LABRADOR train braking model (WILAC is already implemented) to allow braking in leaf layer conditions to be carried out
 - Implementation with multi-body dynamics models of trains to study full train behaviour in leaf layer conditions

- **The Model is available:**
 - If you would like to have the code please email roger.lewis@sheffield.ac.uk in the first instance

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Future Work



- Validate against data gathered using Trib Train and used to develop WSPER rig
- Consider time as an input variable in creep force modelling (for water, leaves, etc.)
- Investigating the role of transients on the creep force curve (for water, leaves, etc.)
- Investigate (leaf) layer degradation
- Link contamination status to variables characterizing the surface condition
- Investigate influence of contact geometry and surface topography on creep force characteristics
- Extension of friction model (Polach model) to adequately represent large range of curve shapes
- Creep-controlled experiments are advantageous to investigate stable regime of creep force curve!



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