International Conference on Train/Track Interaction & Wheel/Rail Interface
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University of HUDDERSFIELD
Institute of Railway Research

Railway turnout damage prediction and design implications

Speaker: Dr Yann Bezin (*IRR Head of Research, Huddersfield, UK)*

Inspiring tomorrow's professionals

Content

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- Background
  - Key issues with Switches & Crossings in relation to the Wheel-Rail Interface
- Key areas of research by IRR
  - EU/National research projects
- How to address key challenges
  - Research tools
  - Vi-Rail utilisation
  - Validation aspects
- Future work and challenges
  - Challenges and opportunities

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Background

Complexity

- Large # of parts
- Wide range of possible layout configuration
- Moving parts & exposed mechanisms
- Mechanical interfaces
- Weak structural components

Non-linearities

- Rail cross sections (bearing surface)
- Structural stiffness (rail bending stiffness, bearers length & ballast support)
- Rail inclination
- Track curvature
- Cant deficiency

S&C key components and damages

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Component	Failures
Cast manganese Casting	transverse fatigue crack (foot or nose)
Crossing nose	wear, plastic deformation, shelling and spalling
Wing rail	wear, plastic deformation, shelling and spalling
bearers	fatigue cracking, voids
switch rails	lipping, head checks, squats, wear
points	all the above + fracture by fatigue
stock rails	lipping, head checks, squats, wear, spalling
slide plates	poor movement (high friction) and ceisure
bearers	fatigue cracking, voids

S&C key components and damages

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Spalling of stock rail

Subsurface initiated fatigue

Lipping of switch/stock rails

C4R Capacity for Rail

Reference*: Capacity4Rail, D131 "Operational failures modes of S&Cs"*

S&C key components and damages

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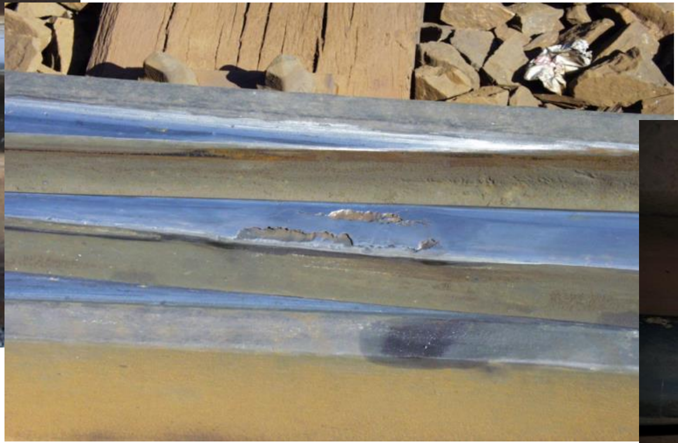
Plastic deformation of wing rails

Spalling of crossings



Spalling & plastic deformation of crossing nose

C4R
Capacity for Rail

Reference*: Capacity4Rail, D131 “Operational failures modes of S&Cs”*

Root causes: dynamic W/R Interaction

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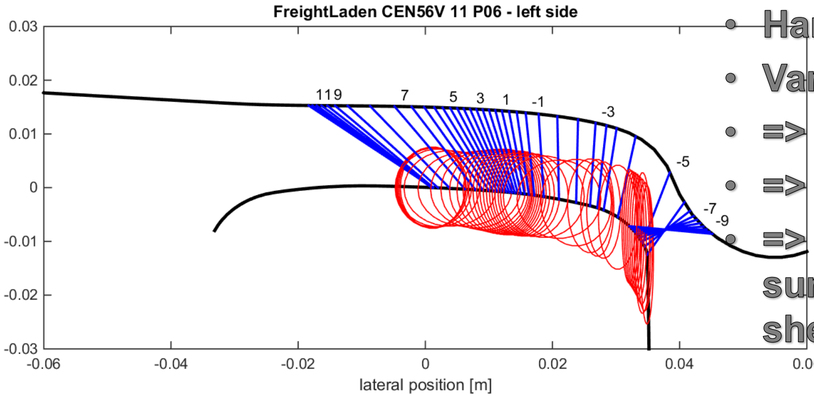
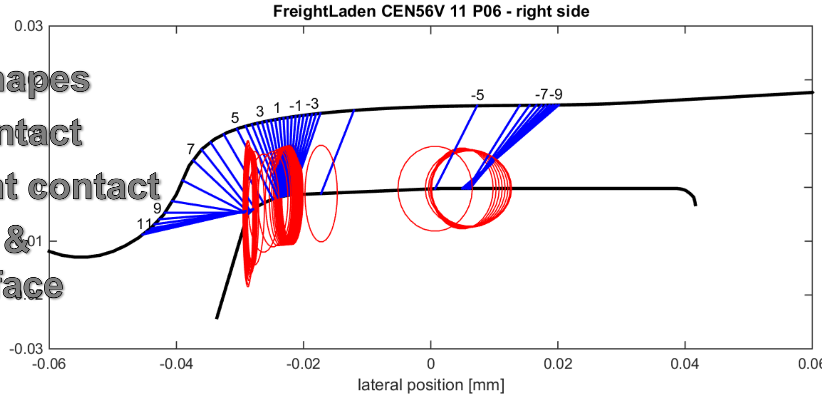
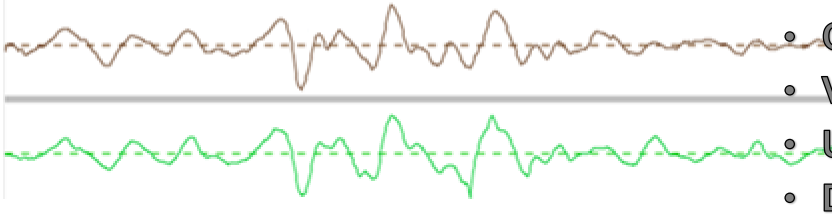
Poor compliance of W-R geometries



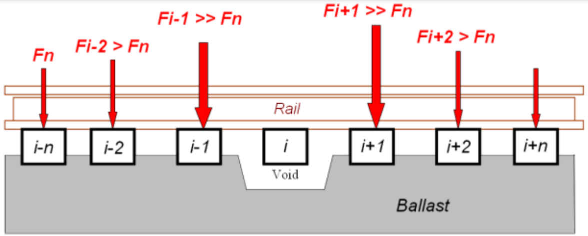
- Harsh interface
- Variable rails shapes
- => Jumps in contact
- => Multiple point contact
- => High normal & surface/subsurface shear stresses



Poor maintenance + support



- Cyclic top/alignment
- Voided/hanging bearers
- Uneven L/R loading
- Differential settlement



Root causes: dynamic W/R Interaction

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Poor compliance of W-R geometries

High rail/sleeper accelerations

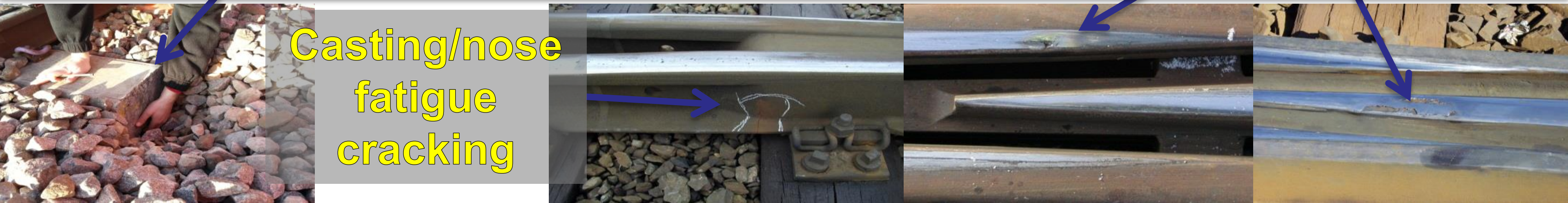
Ballast void and settlement

Increased Dynamic Forces

High normal & shear stresses

rail wear, fatigue & deformation

Poor maintenance + support



Root causes – Influential factors

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- **Design** (system level => vehicle-track…)
- **Environmental** (incl. extreme weather)
- **Installation/set-up** (human factor, tolerances…)
- **Maintenance** (mechanised/manual…)
- **Manufacturing** (processes/tolerances/…)
- **Operational** (speed, loading regime, traffic mix, tonnages…)

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Capacity for Rail

Reference: D131 Operational failure modes of SCs

Key areas of research & development

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<u>Eslöv-Sweden test site</u>:
- Kinematic Gauge Optimisation
- Resilient stiffness

<u>Haste-German test site</u>:
- Crossing nose shape (e.g. MaKüDe)
- Material (built-up)

<u>Simulation software</u>:
- Benchmarking
- KGO optimisation
- Support stiffness variation

<u>Simulation of</u>:
- Derailment analysis
- Switch rail shape optimisation
- Impact of wheel shape
- Under sleeper pads
- Innovative structures

<u>Material</u>
- Higher steel grades

<u>Concept evaluation</u>:
- New switch concepts
- New drive and lock devices

<u>FP6</u>
Innotrack

<u>FP7</u>
Sustrail
Rivas
DRail
Capacity4Rail

<u>H2020</u>
In2Rail…
…Shift2Rail

Towards demonstration of key innovations

SEVENTH FRAMEWORK PROGRAMME

THE FRAMEWORK PROGRAMME FOR RESEARCH AND INNOVATION HORIZON 2020

Simulation tools – what we need…

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Vehicle

- ☑ *Unsprung mass*
- ☑ *Primary stiffness*
- ☑ *Traction/braking*
- ☑ *PYS and steering*

Wheel-Rail

- ☑ Variable rail (3D interpolation)
- ☑ Variable friction coefficient (switches)
- ☑ Non Hertzian multiple contact
- ☒☑ Special materials effect on wear and fatigue (Hv)

Track

- ☑ Tuned 9dof model
- ☑☒ Discrete support model (casting, bearer length/mass, baseplates, variable support, …) [FlexTrack]

Available simulation technology

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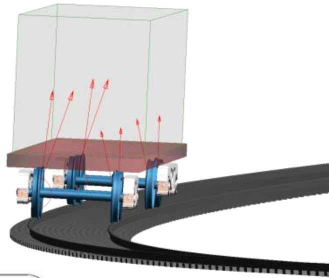
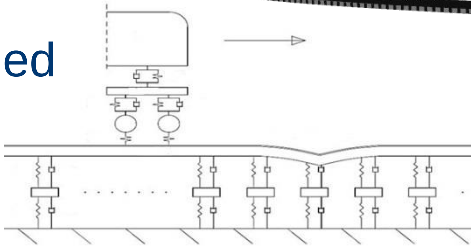
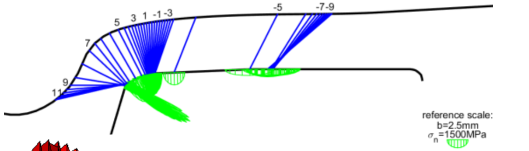
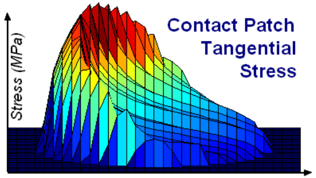
- Vehicle multibody system dynamics
  - Prediction of vehicle behaviour and WRI forces
- Vehicle-track interaction dynamics
  - Prediction of WRI forces based on simplified or detailed track response
- Wheel-rail contact conditions
  - WRI forces and contact conditions (normal and tangential)
- Wear/damage prediction & summation
  - Based on any of the above









Example key output SUSTRAIL

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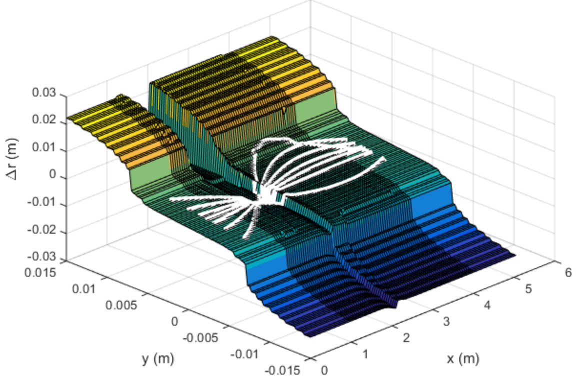
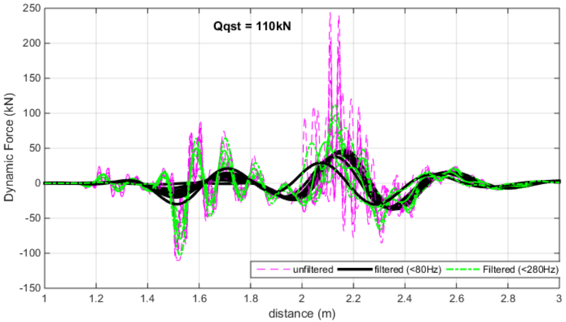
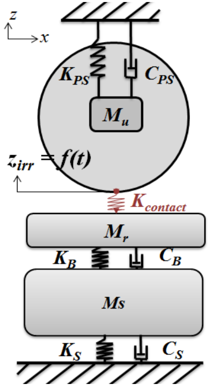
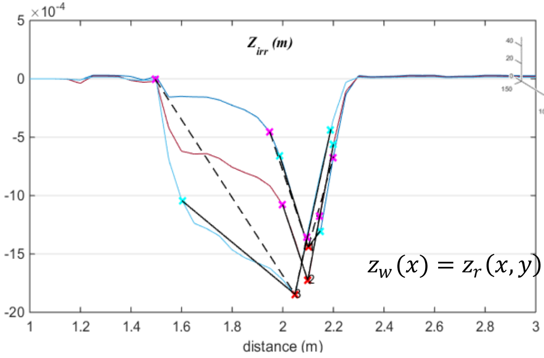
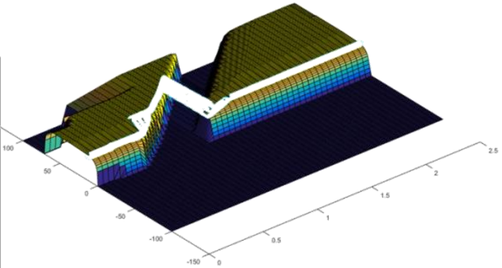
- Axle kinematic motion
- Vertical wheel motion => dip angle
- 3-*dof* wheel-track MBS model
- Dynamic $F_{vertical}$ prediction => P2 force











$$z_w(x) = z_r(x, y) + r_0 - \Delta r(x, y)$$

SUSTRAIL

Contact condition and contact stresses

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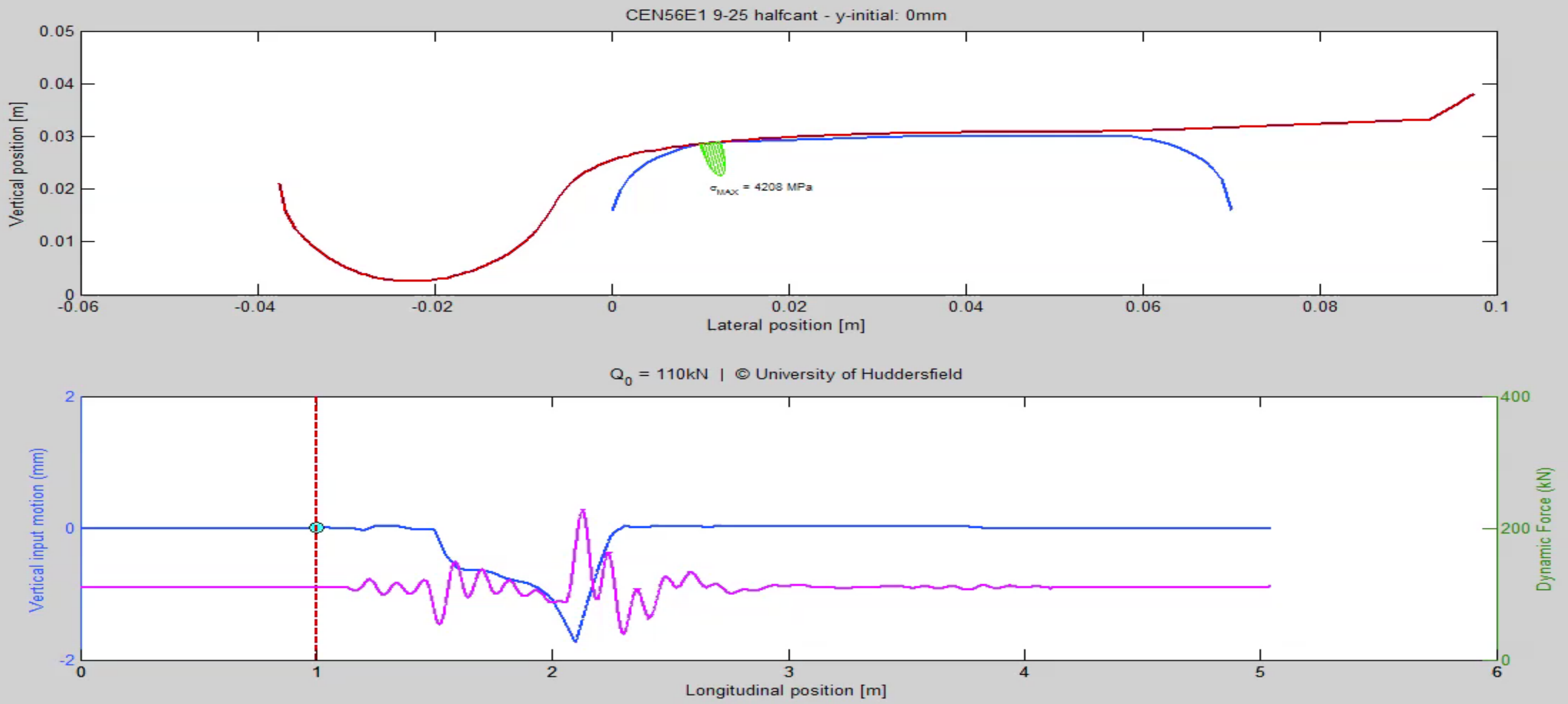

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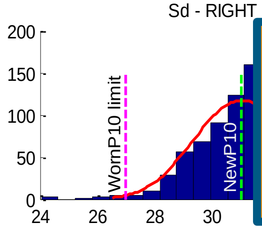
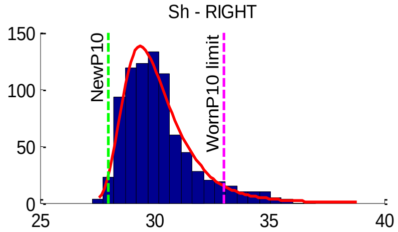
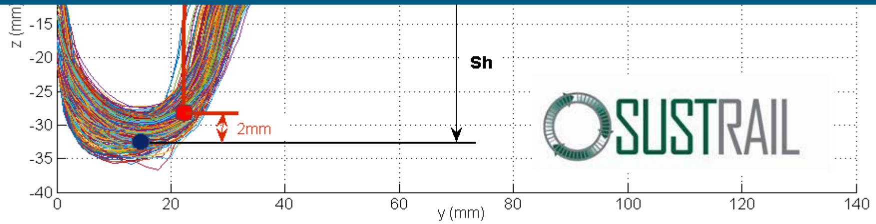
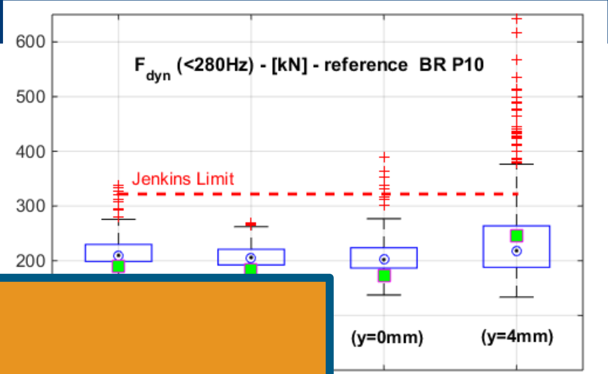
Example key output SUSTRAIL

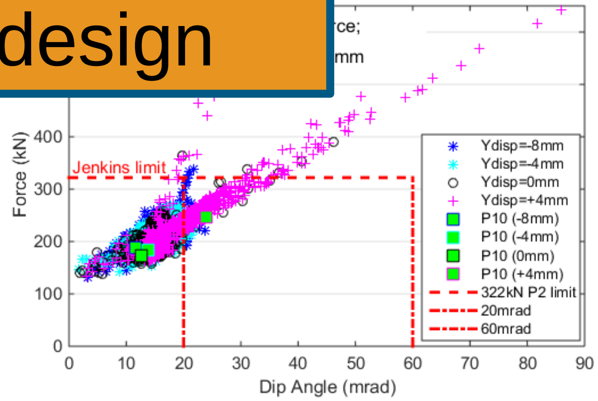
- Parametric study: 800+ wheel pairs
  - Prediction of dip angle and P2 force levels











Shape matters!
Take a system approach to design

References:

BEZIN, Y., COLEMAN, I., GROSSONI, I., NEVES, S., HYDE, P., BRUNI, S., ALFI, S., RANTATALO, M., JÖNSSON, J., ASLAM, M., LAMBERT, R., BEAGLES, A., FLETCHER, D. & LEWIS, R. 2015. D4.4 Optimised switches and crossings systems, *SUSTRAIL 265740 FP7*.

BEZIN, Y., GROSSONI, I. & ALONSO, A. 2014. The Assessment of System Maintenance and Design Conditions on Railway Crossing Performance. *Proceedings of the 2nd International Conference on Railway Technology: Research, Development and Maintenance*. Civil-Comp Press, Stirlingshire, United Kingdom.

Example key activities Capacity4Rail

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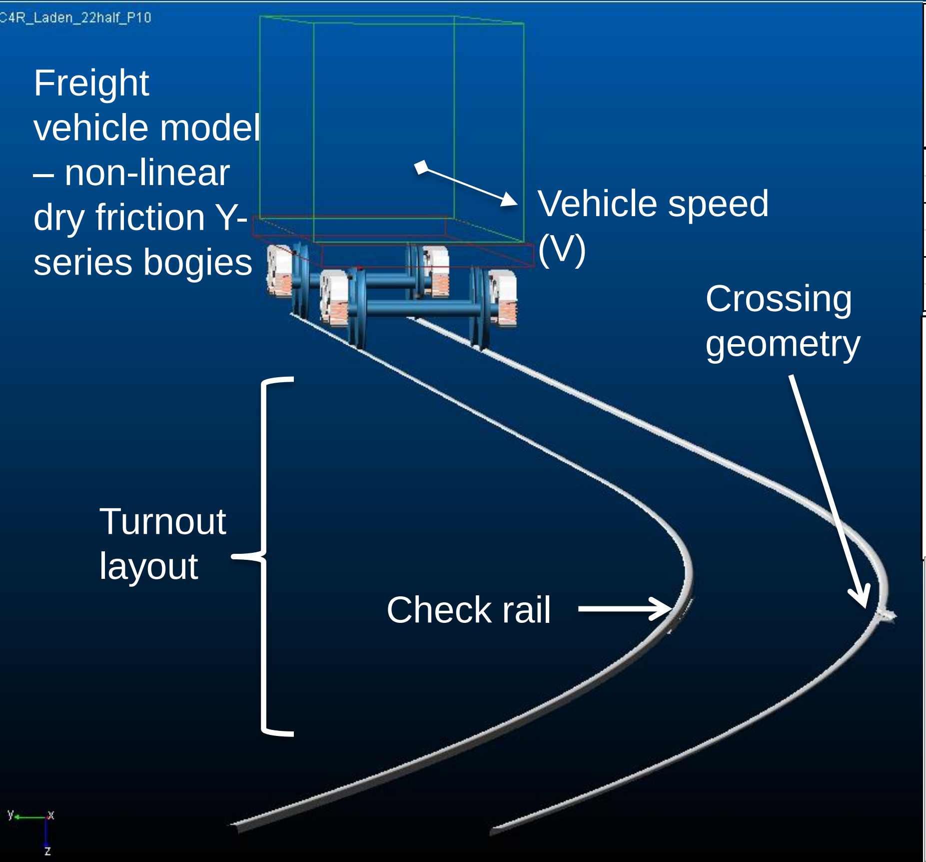
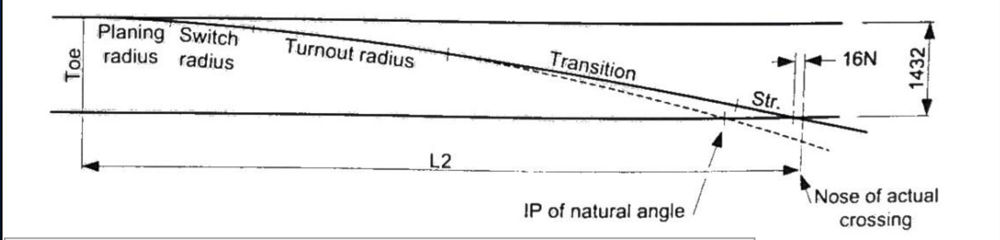
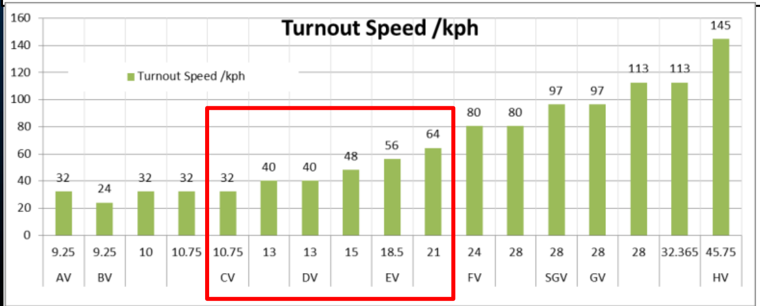


Switch	Crossing 1in~		Lead Lengths			Radii			Length			Turnout Speed /kph
	Natural	Actual	Lead L2 Toe to nose	nose across a 1970 interval	Toe to toe	Planing radius	Switch radius	Turnout radius	Length of Planning P	Length of transition	Length of straight to nose	
CV	9.25	10.75	25448	5360	56256	287251	245767	245767	4250	7366	584	32
	9.25	13	27007	6513	60526	287251	245767	245767	4250	13000	3271	40
DV	10.75	13	30125	6513	66762	367038	331687	331687	5200	10630	964	40
	10.75	15	31713	7533	70960	367038	331687	331687	5200	17455	2534	48
EV	15	18.5	42017	9315	93349	739696	645116	645116	7000	16255	1560	56
	15	21	44066	10585	98718	739696	645116	645116	7000	24555	3605	64





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Contact condition and patch shapes

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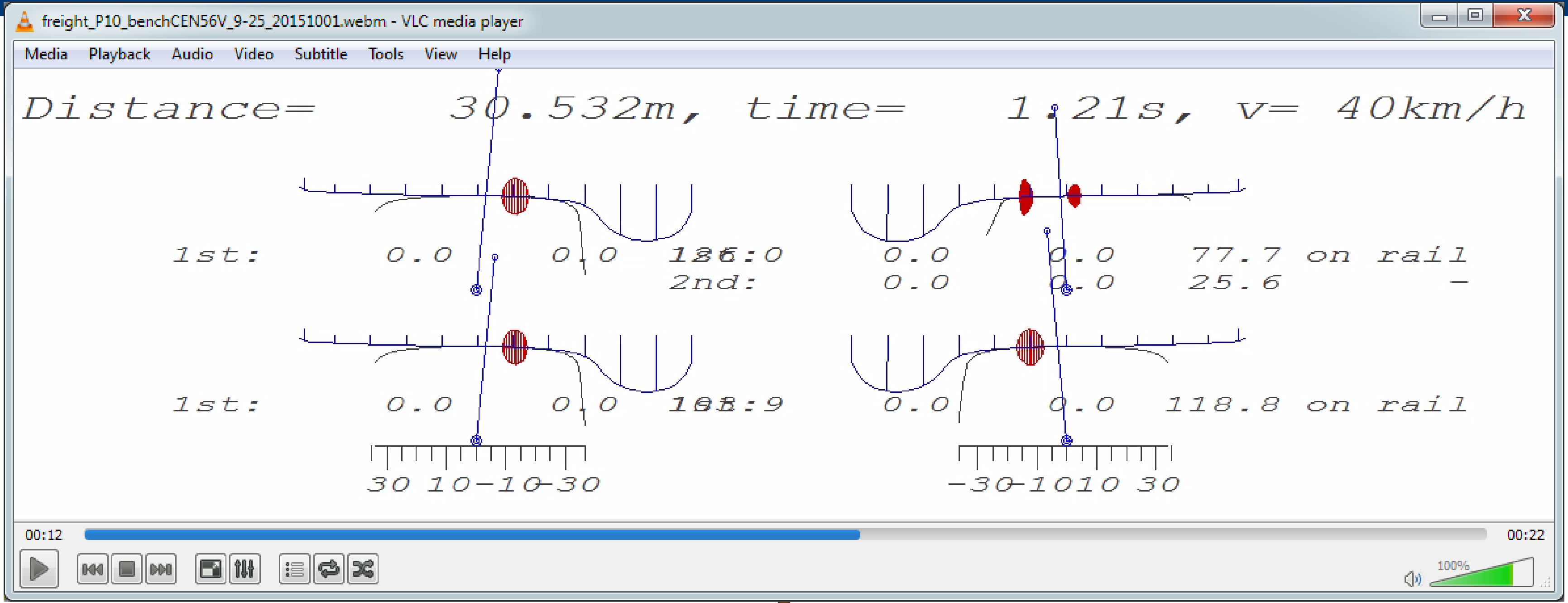

freight_P10_benchCEN56V_9-25_20151001.webm

Crossing geometry design and input to simulation

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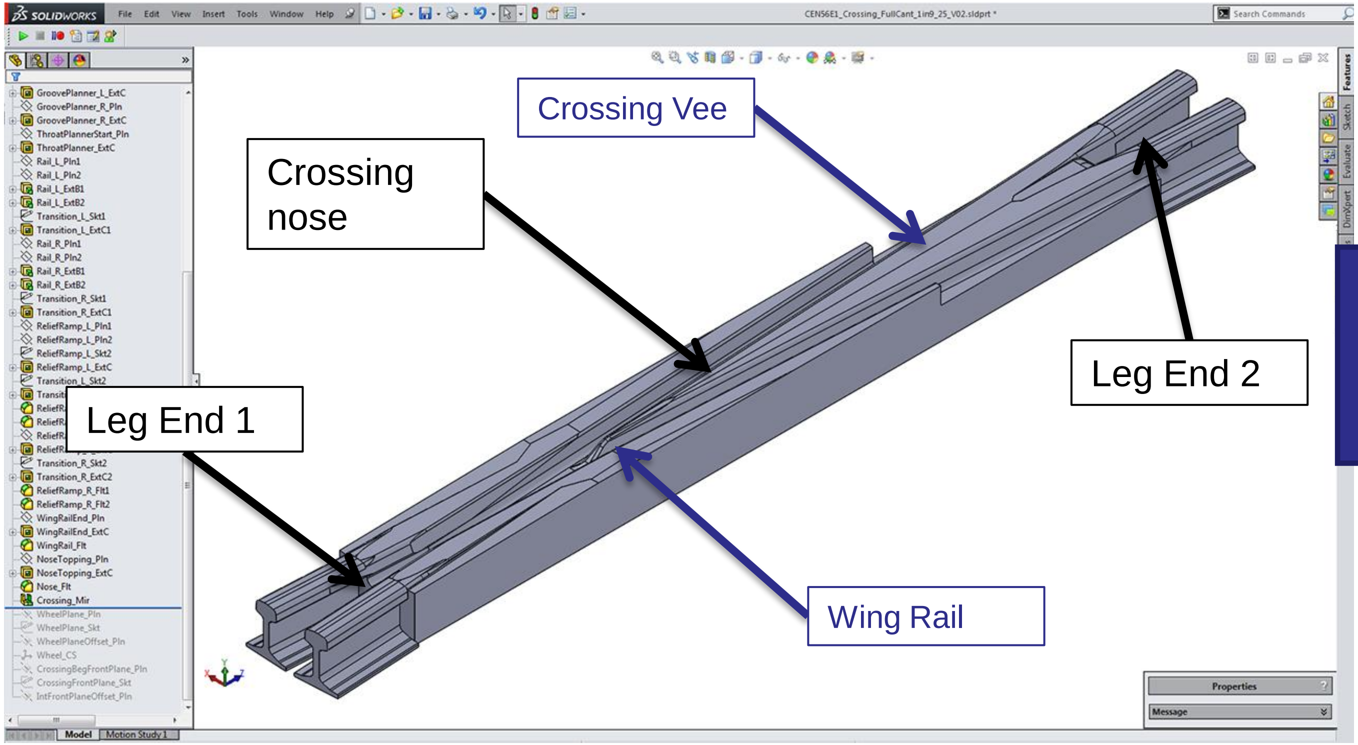
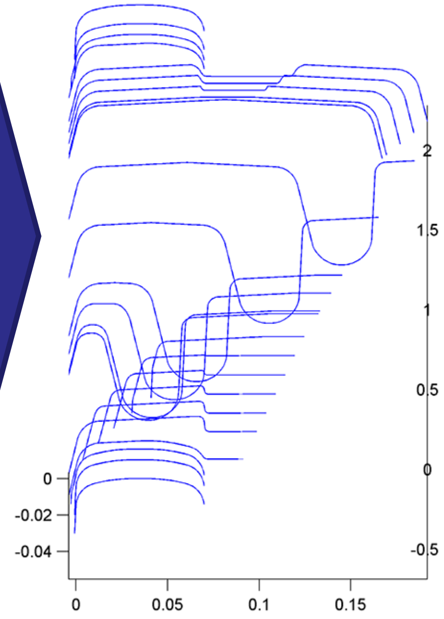


Matlab pre-processed geometry ready for 3D interpolation



Example design geometry evaluation

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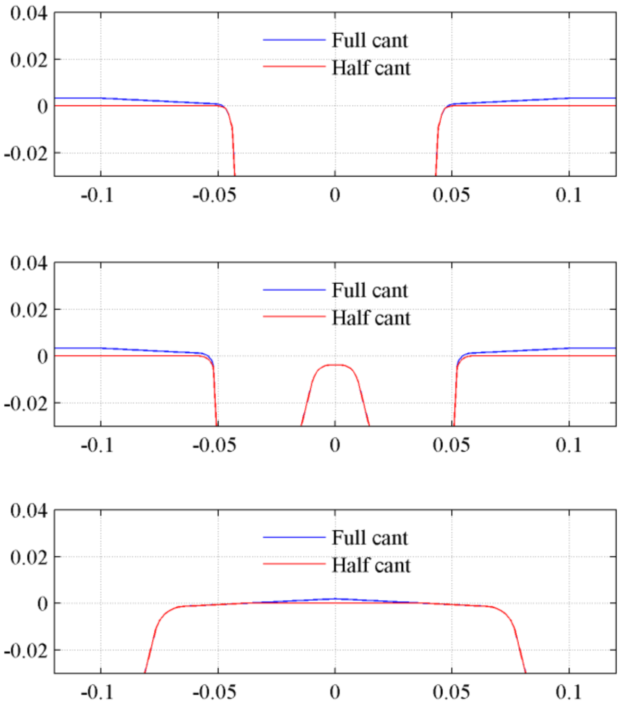
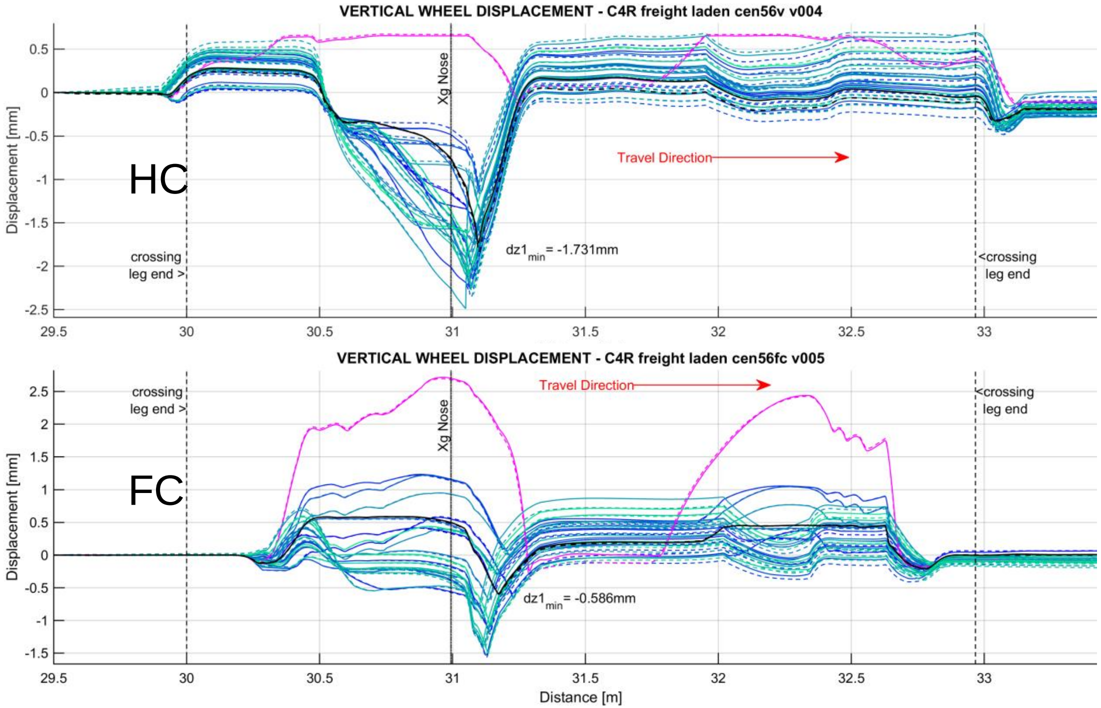
UK CEN56 vertical HC vs FC



Simulated wheel vertical motion through crossings



Example design geometry evaluation

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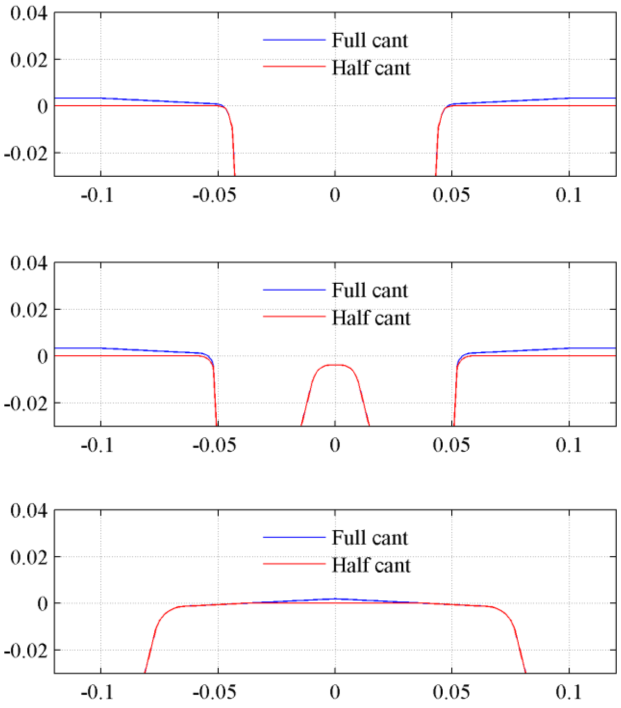
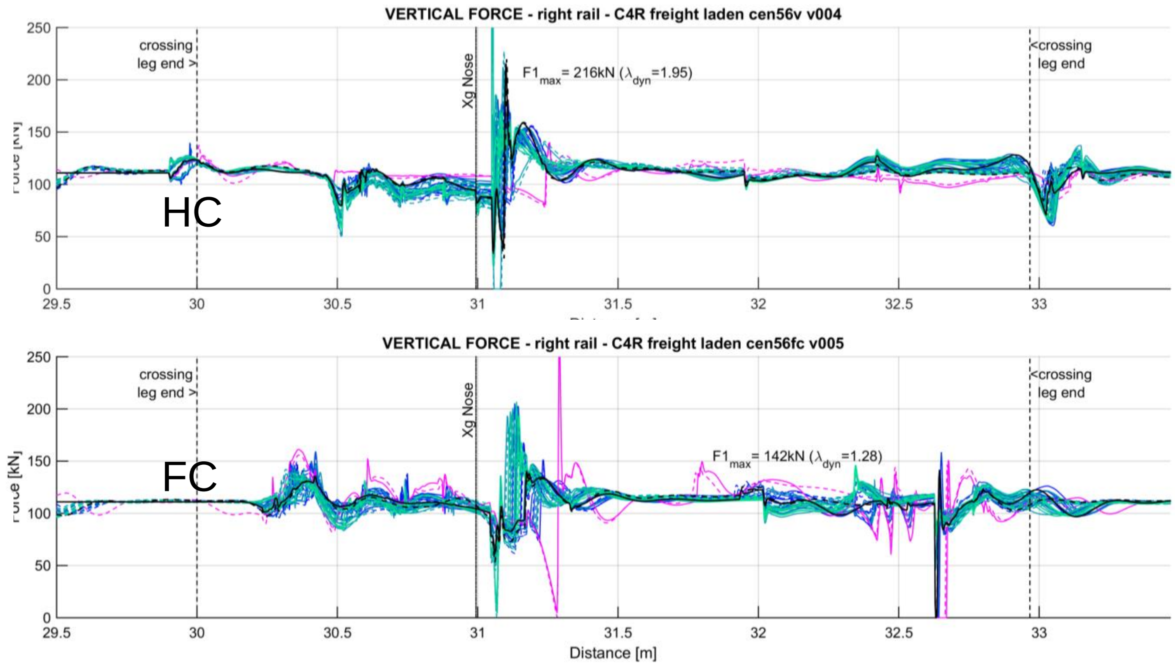
UK CEN56 vertical HC vs FC



Simulated vertical vertical contact force



Travel Direction

Example design geometry evaluation

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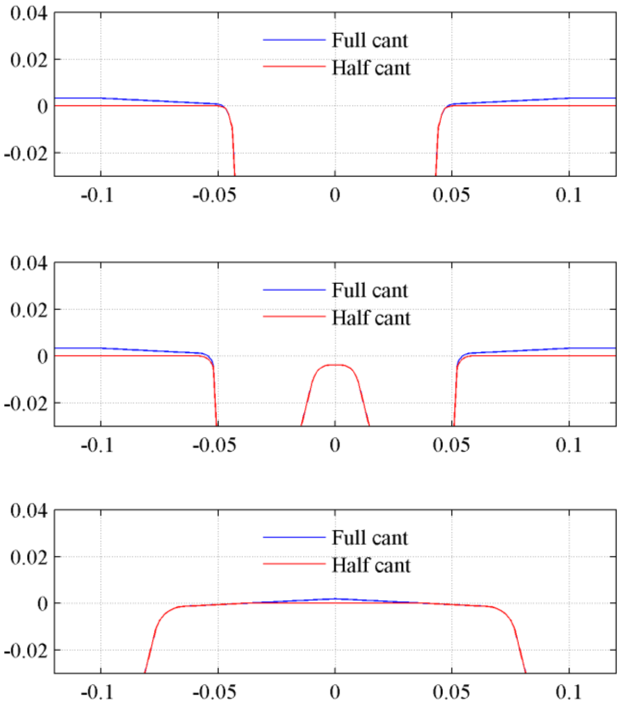
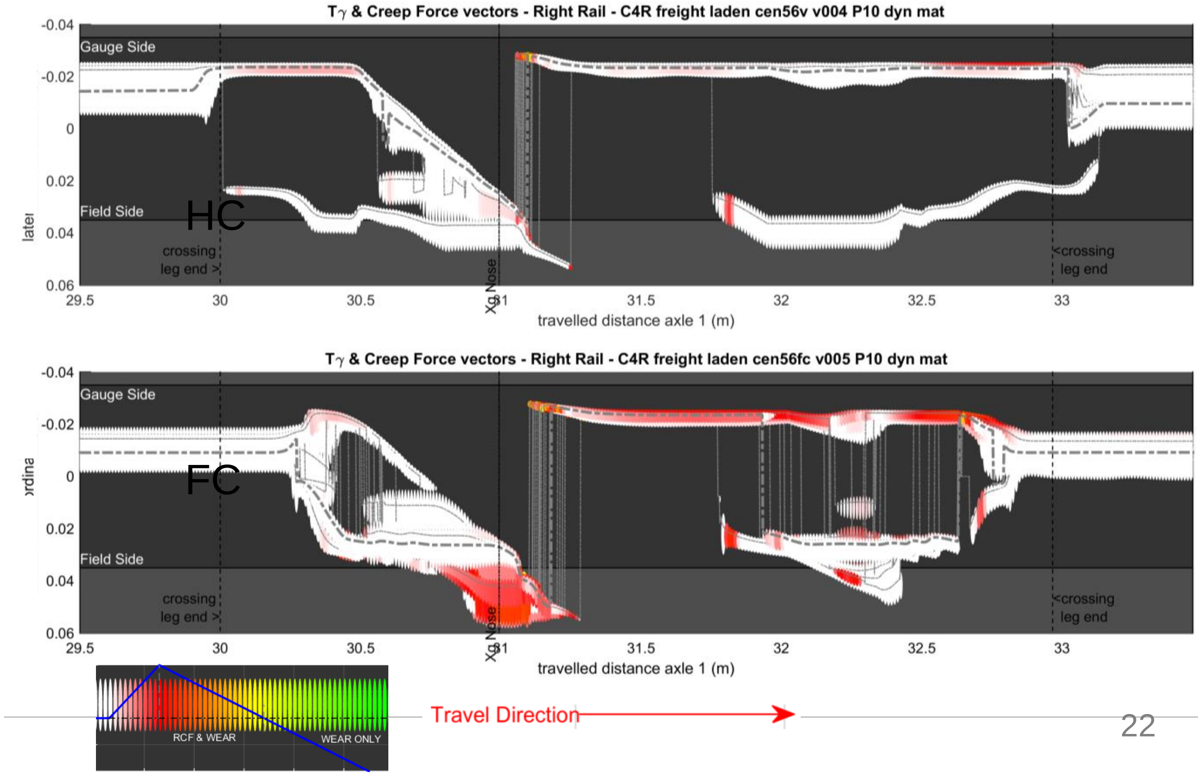
UK CEN56 vertical HC vs FC



Predicted surface damage (crack initiation and wear)



Key conflicting requirements

- Engineering design vs cost
  - Highly engineered material specification (at what cost?)
  - Resilient track construction (at what cost)?
  - Standardisation versus customisation?
- Through vs diverging route
  - Traffic mix consideration in design vs generic design!
  - Trade-off in rail shapes and layout geometry optimisation
  - Acute vs Obtuse
- Facing vs trailing move
  - Trade-off in rail shape and layout geometry optimisation
- Wear vs RCF
  - Competing phenomena

Validation Challenges

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- Validation of rail damage prediction
  - Based on specific site observation + stochastic data collection
  - Fast and reliable data collection (vehicle inspection vehicles?)
- Material characterisation data and experiments
  - Twin disc rigs for:
    - Wide range of traction and normal pressure
    - full scale where possible…
    - Replicating S&C 'harsh' conditions (high curvature)
    - Replicating S&C materials (cast Mn, EDH, hardened steel e.g. 350HT)
  - Plastic deformation
  - Residual strains in highly stressed contained material
- Full scale testing for close to reality WRI conditions…

Validation Challenges

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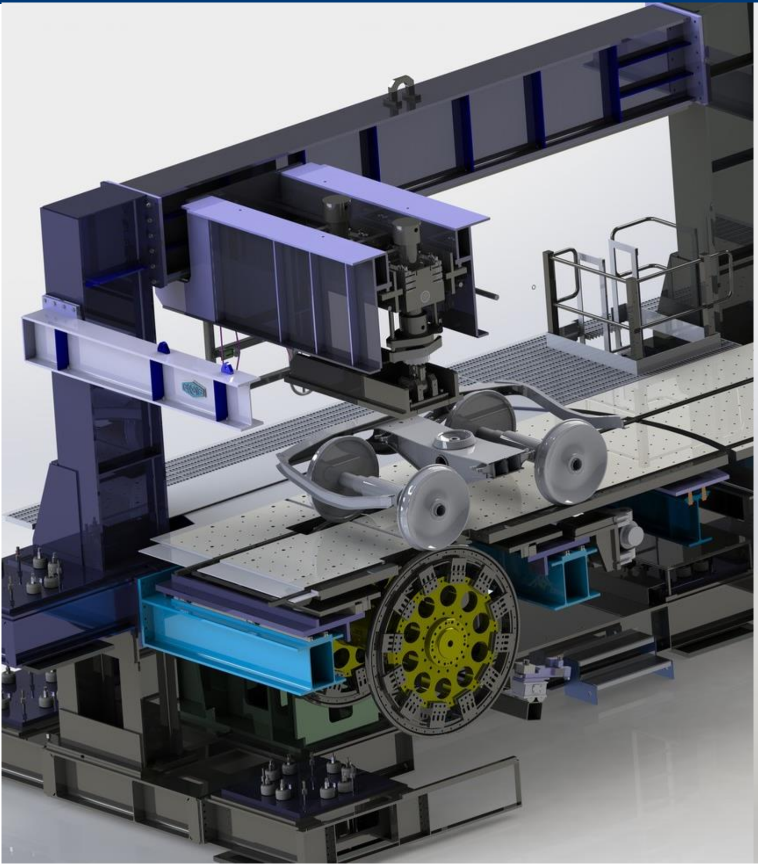

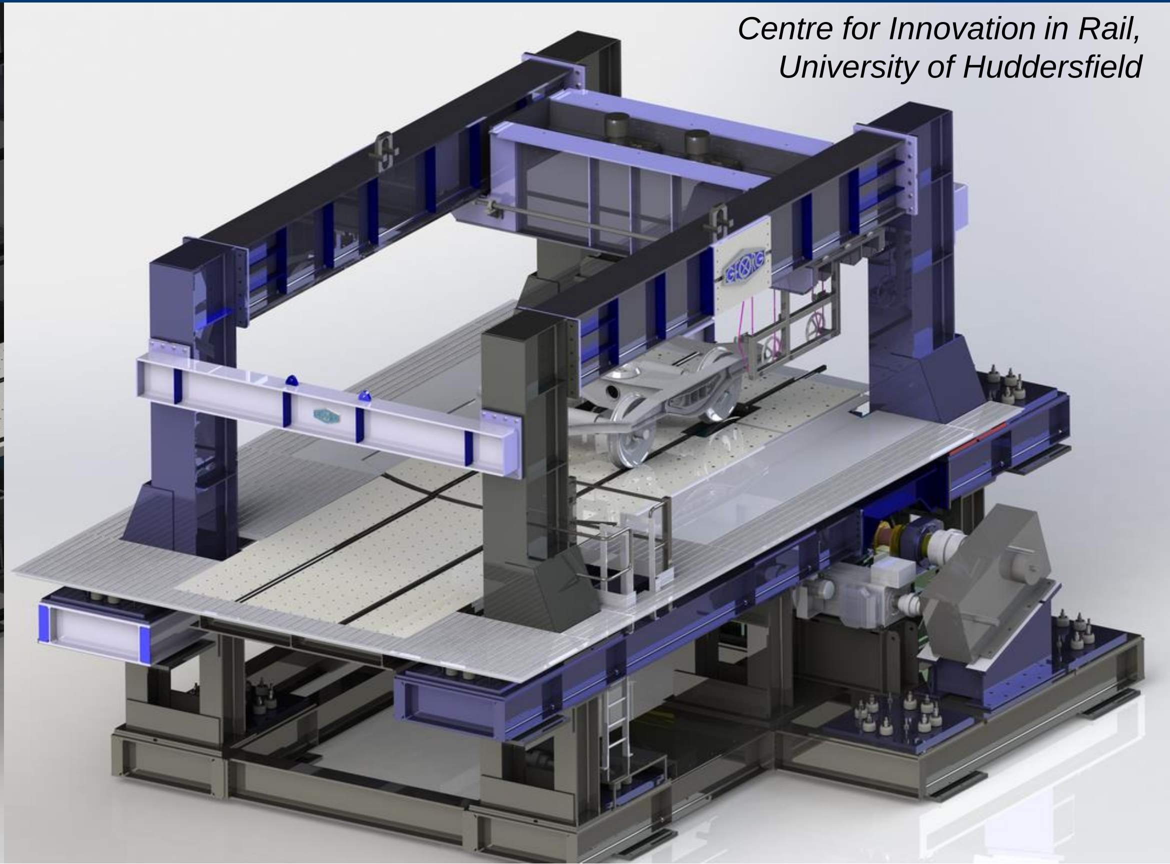

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Few words of conclusion

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- Key damage mechanisms in S&C relate to wheel-rail interface => *heavily strained interface!*
- Key areas of collaborative research in EU are *geometry/shape optimisation* and *improved support stiffness* (upgrade to ballasted & novel track forms)
- Available simulation techniques enable *predicting key damages* (location, intensity and accumulation) and qualitative assessment of different designs
- exchange of *data* and *testing resources* is key to validation as a first step towards innovation selection and evaluation in track
- This is a system - consider both sides of the interface!

Thank you for your attention.

Contact: Yann Bezin (y.bezin@hud.ac.uk)

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SUSTRAIL

C4R Capacity for Rail

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