C4R

Capacity for Rail

S&C: Understanding Root Causes & Assessing Effective Remedies

C4R Final Dissemination Event, Paris 15th March 2017

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Seventh Framework Programme

Overview

1. **Brief review of key damages and root causes in relation to S&C vehicle-track interaction**

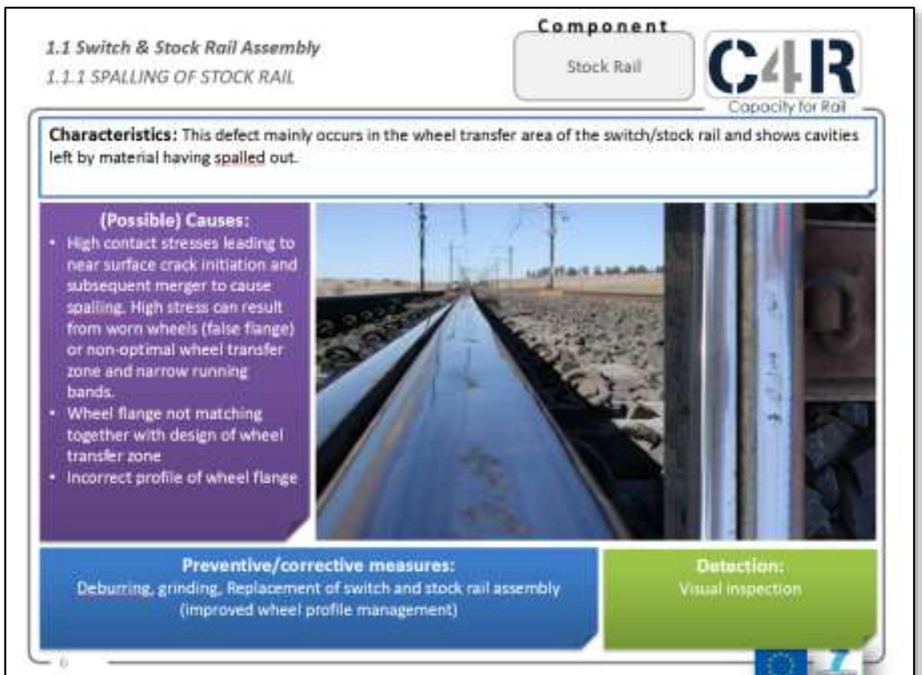
2. **Understanding/predicting wheel and rail interaction at S&C**

3. **Predicting damage mechanisms in rails and support and identifying the key drivers**

4. **Assessing the benefit of crossing geometry change and other innovations on the system performance**

C4R S&C Failure Catalogue

- #44 Failures catalogued in public Deliverable-13.1
- Presented at 1st Dissemination event, Paris June 2015



Components damages in S&C

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Switch and stock rails

- Lipping & spalling
- Head checks
- Squats
- wear

Points

- Additional fracture by fatigue

Bearers

- Fatigue cracking
- Vertical movement and hanging
- Lateral shift

Slide plates

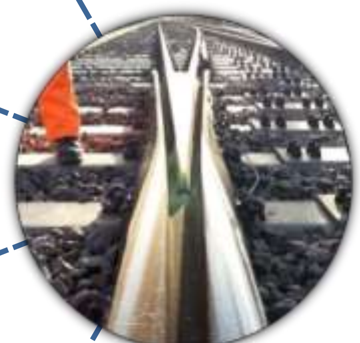
- Poor movement (high friction)
- Seizure

Components damages in S&C

Capacity for Rail

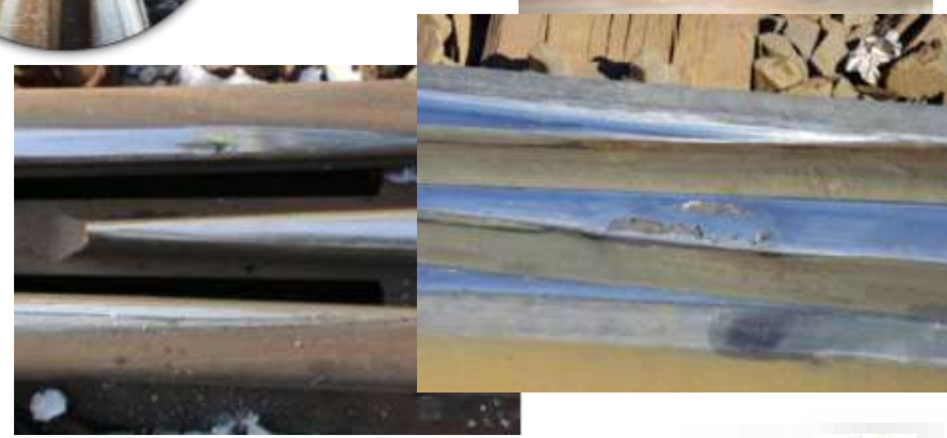
Cast crossing
- Transverse fatigue crack (foot or nose)

Crossing nose & Wing
- Wear
- Plastic deformation
- Shelling & spalling

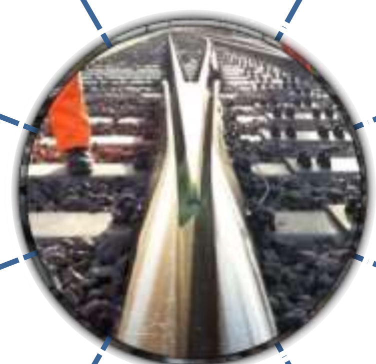


Check rails
- Excessive Wear

Bearers
- Fatigue cracks
- Voids & hanging



Components damages in S&C



Cast crossing
- **Transverse fatigue crack (foot or nose)**

Crossing nose & Wing
- **Wear**
- **Plastic deformation**
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Check rails
- Excessive Wear

Bearers
- **Fatigue cracks**
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Root causes

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System Design
vehicle-track,
wheel-rail…

Operational
speed, loading,
traffic mix…

Environmental
local and weather
variations…

Manufacturing
processes &
capabilities…

Installation/set-up
tolerances and
human factors…

Maintenance
frequency,
mechanised/manual
repairs…

2) Vehicle-track and wheel-rail interaction

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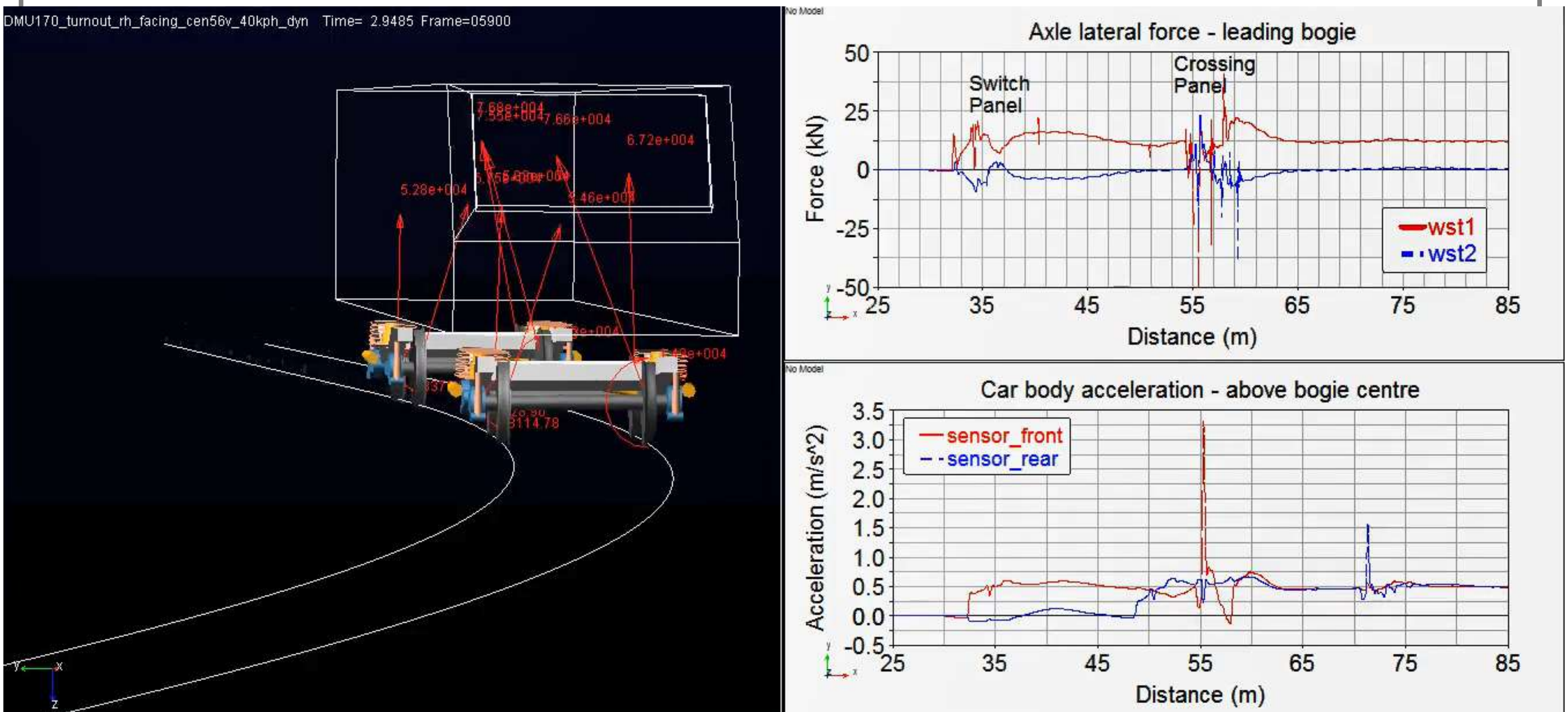
Fundamental behaviour in S&C



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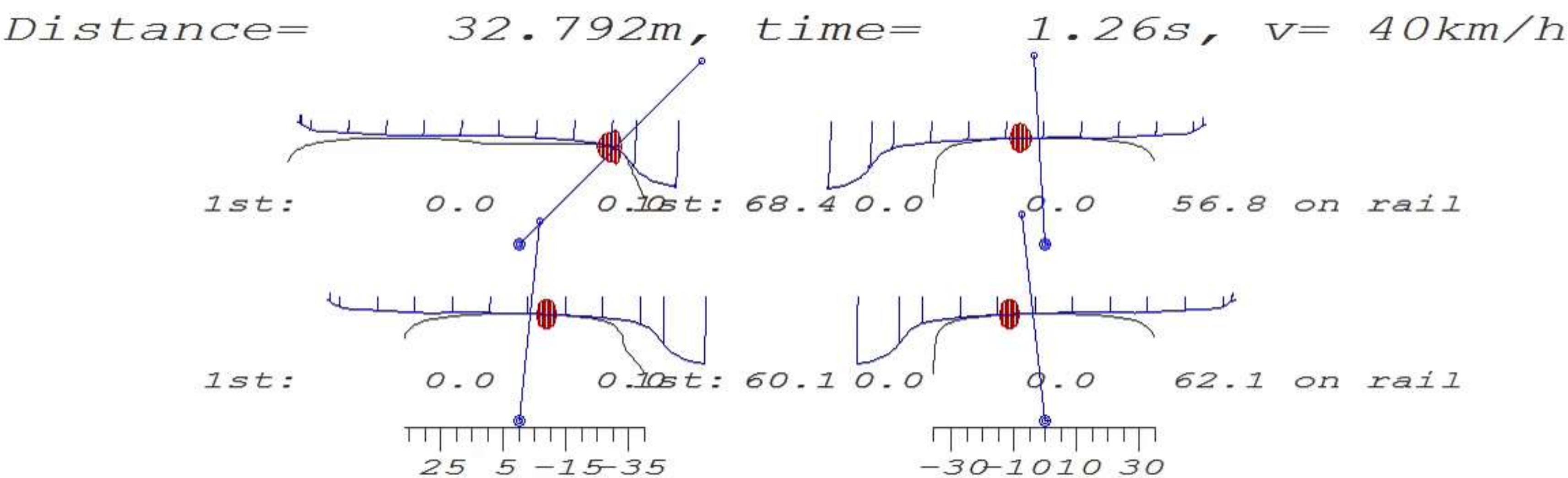
Fundamental behaviour in S&C



Change in rolling radius difference (left/right) as stock rail moves outward and point of contact also

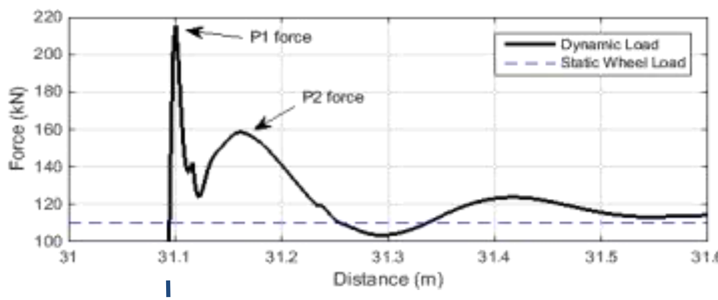
↳ induces a steering of the wheelset (angle of attack)

↳ and associated lateral steering forces (also the case on through route to a lesser extent)

↳ Jump (double) point contact introduces higher frequency force disturbances

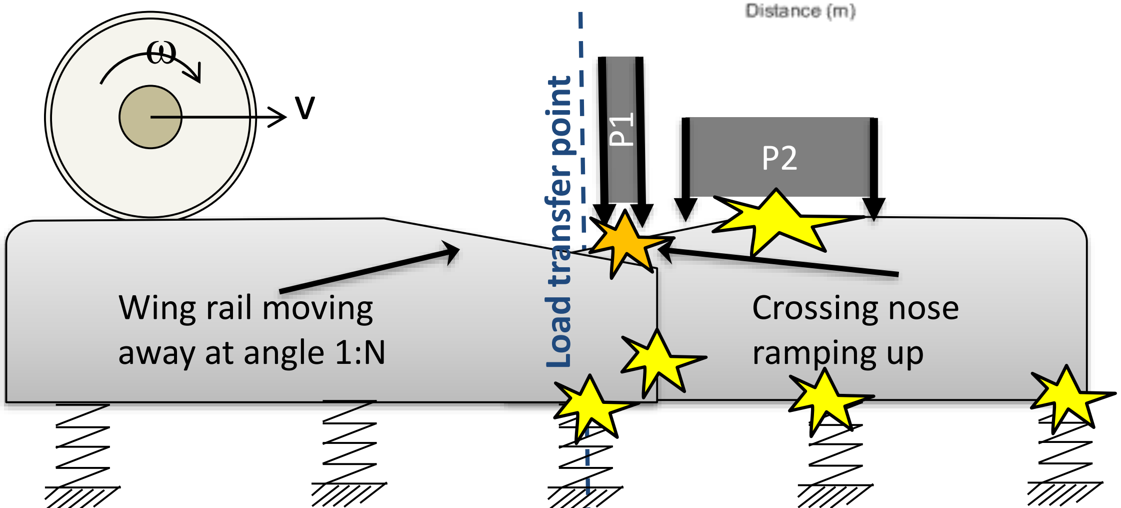
Fundamental behaviour at crossing

Key driver:
Speed (V)
Dip angle (α)
Track & wheel mass (M)
Track Stiffness (K)



Jenkins 74 "The effect of track & vehicle parameters on W-R vertical dynamic forces"

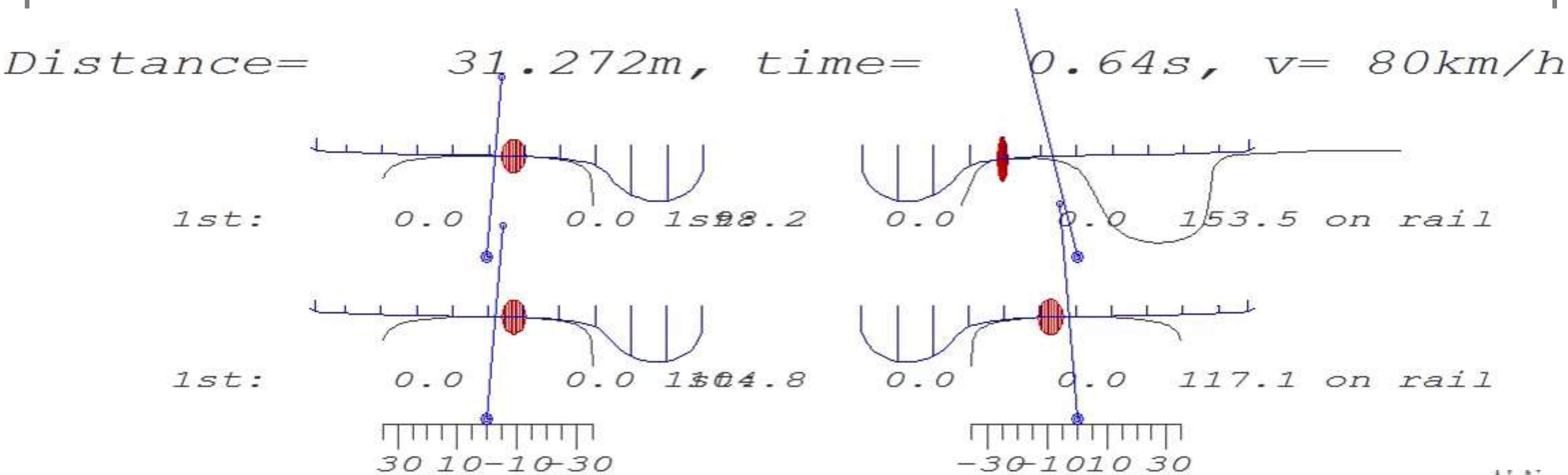
P1	**P2**
< 1ms	< 10~20ms
fcy ≈ 500-2kHz	*fcy* ≈ 50-120Hz
Wheel and track mass Contact stiffness	Wheel and track mass, rail elasticity Ballast support stiffness
Rail head damage (plastic deformation, subsurface fatigue) and rail fatigue	**Rail head damage, ballast degradation, sleeper fatigue and rail fatigue**

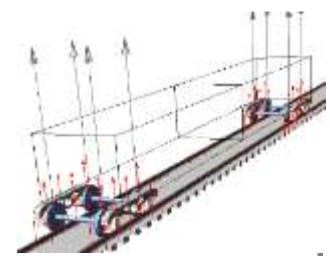


P1 peak position = f(V) **few [cm]**

P2 peak position = f(V) **[0.1~0.9m]**

Fundamental behaviour at crossing

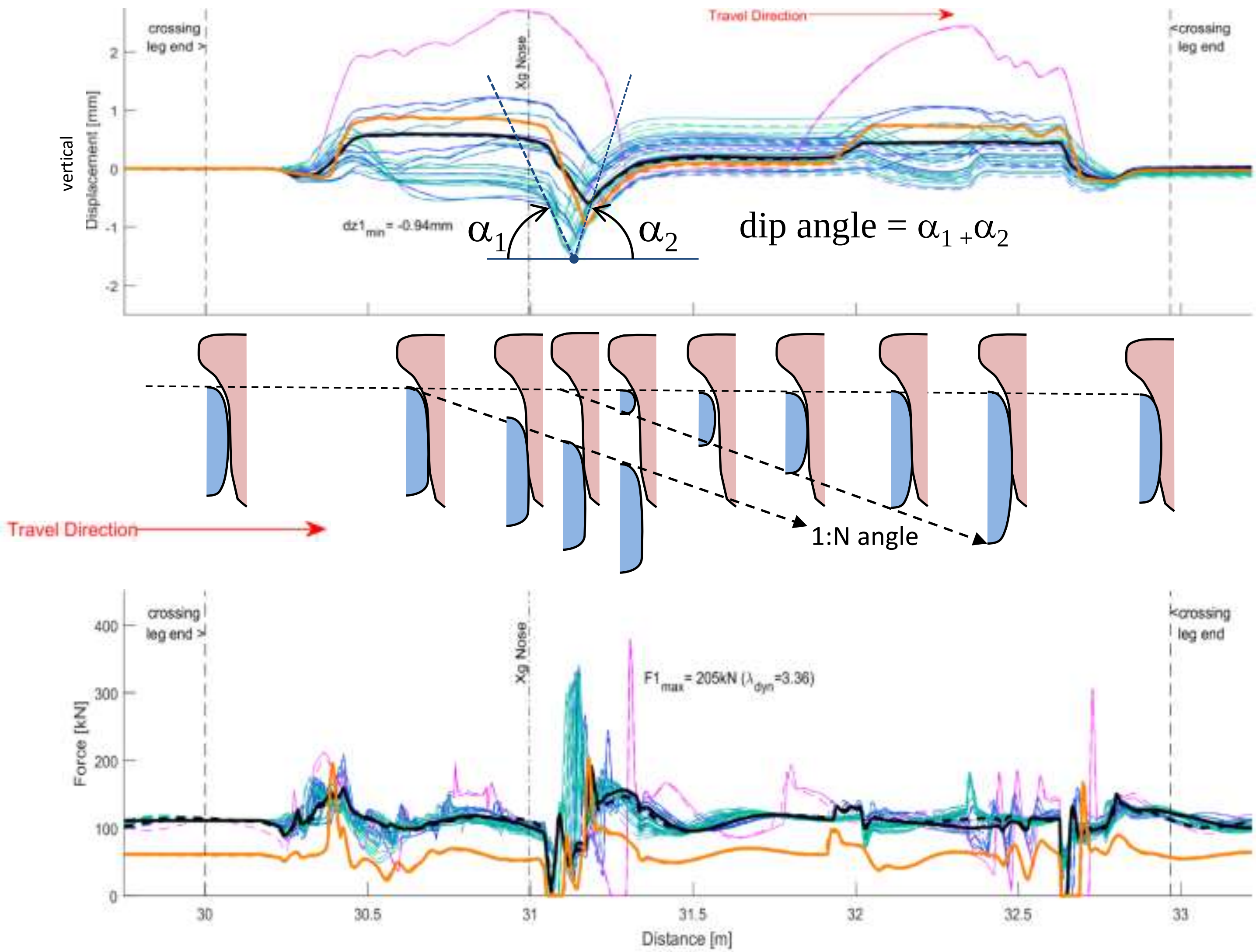




Through the crossing the loading is mainly vertical

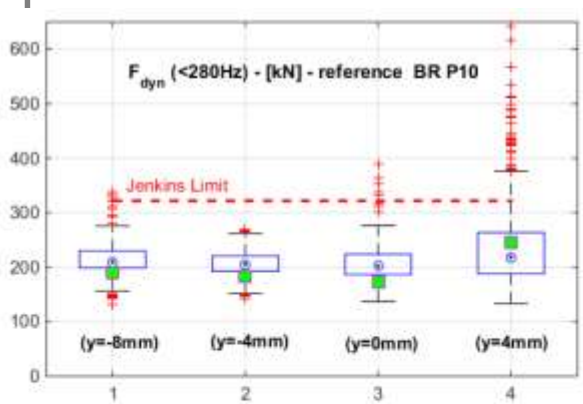
- ↳ Although lateral impact load is also present: RRD ⇨ angle of attack + lateral offset in diverging routes
- ↳ Jump (double) in point contact at entry/exit of casting geometry (smoothed in reality by manual and operational grinding)
- ↳ Vertical impact at load transfer between wing and nose (vice versa)

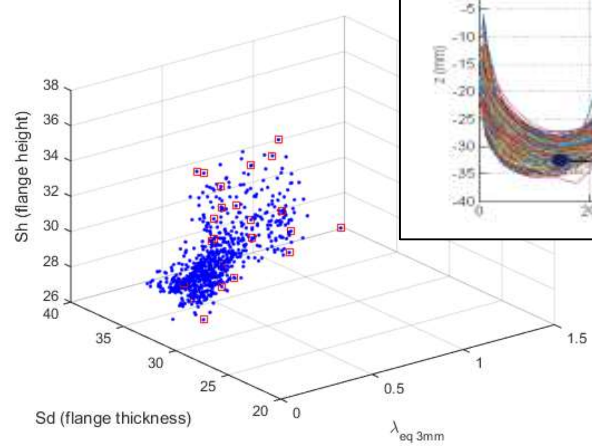
Fundamental behaviour at crossing

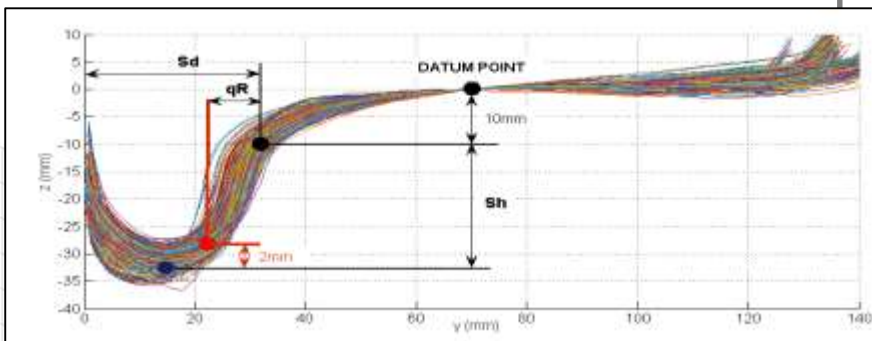


Fundamental behaviour at crossing

- More parameters affecting reaction forces
  - Range of wheels and crossing geometry shapes
  - Vehicle types and steering ability (PYS)
  - Axles lateral position and angle of attack
  - Track geometry and misalignment
  - Support type and conditions
  - Direction of travel (through/diverging-facing/trailing)







3) Predicting damage mechanisms and identifying key drivers

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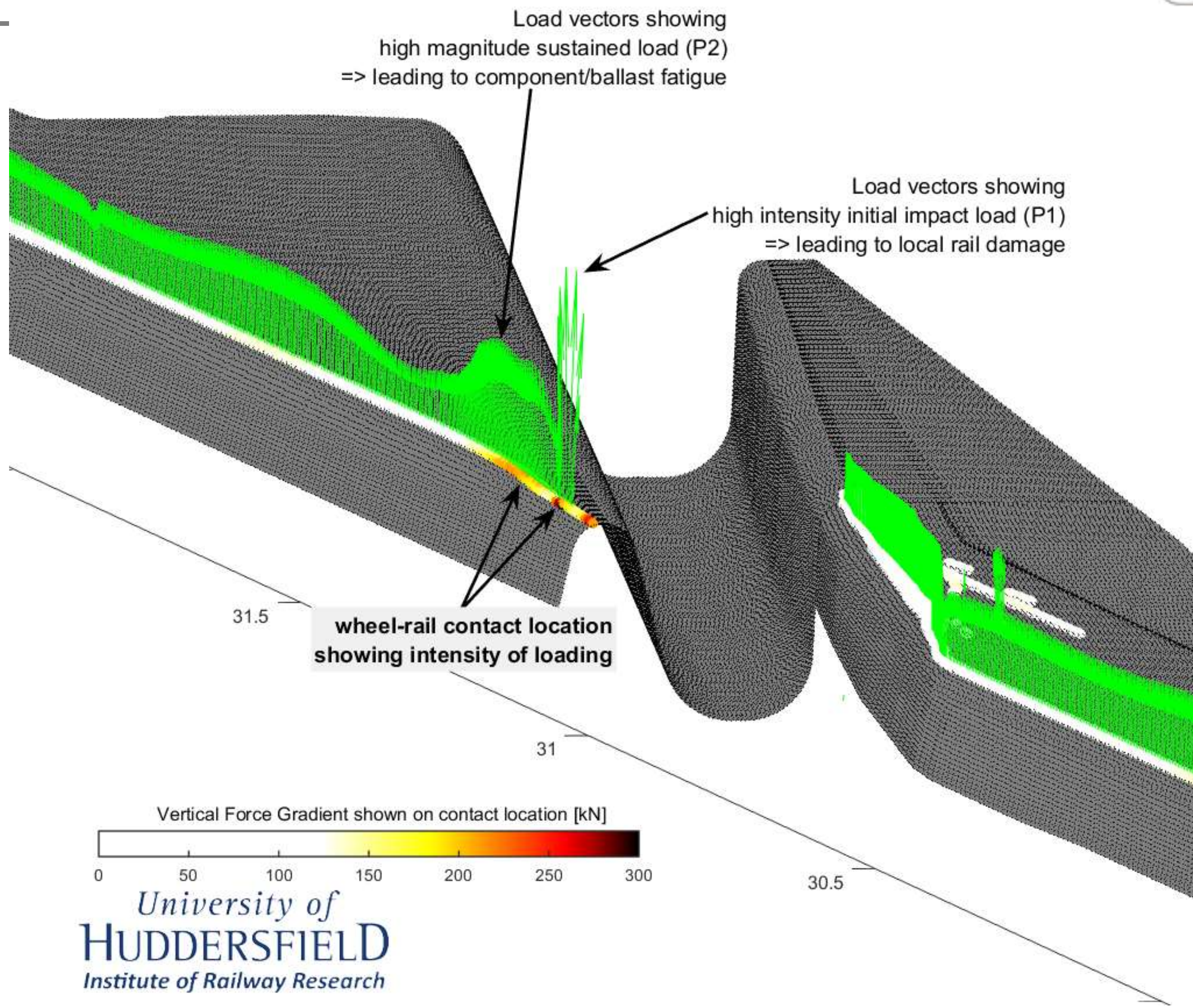
Observing & predicting damage forces



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Observing & predicting w-r interaction

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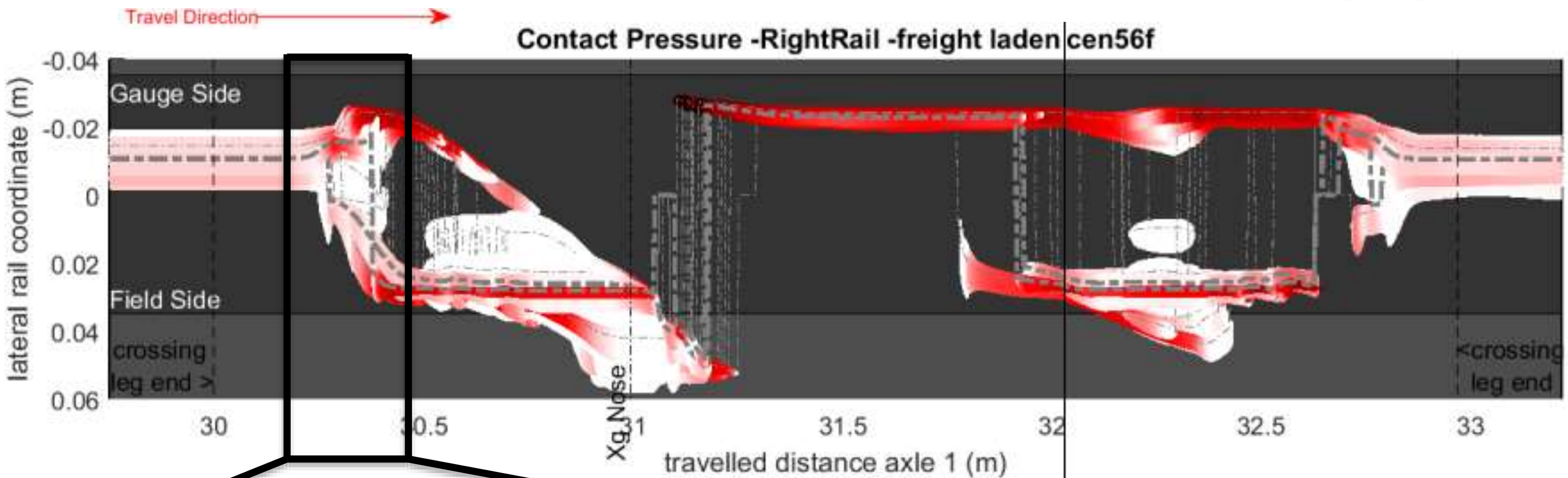
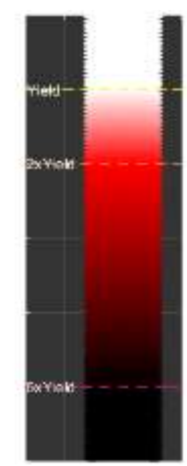
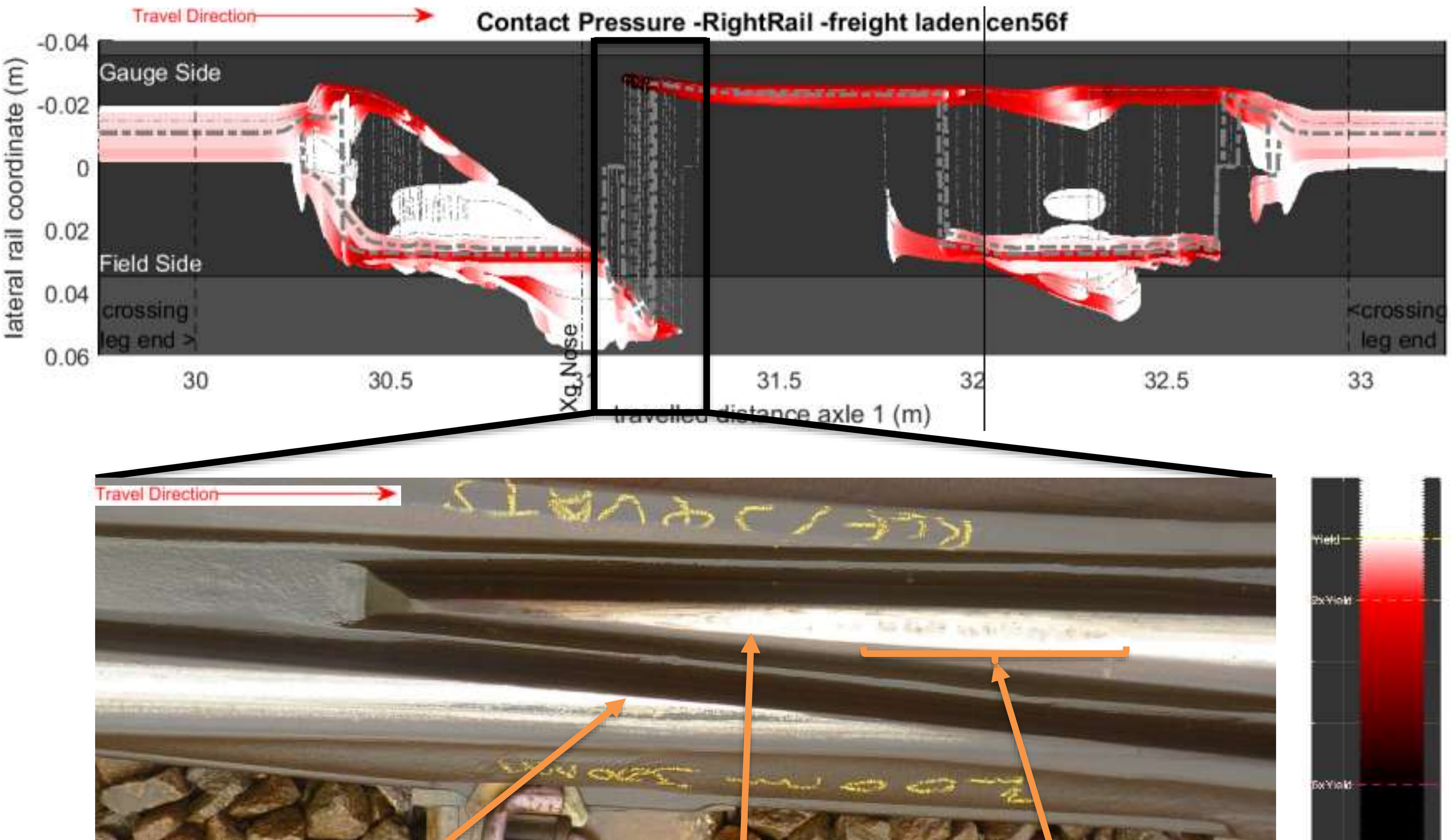


x-dimension not to scale



Rapid change of contact in leg ends; multi point contact; high pressure

Observing & predicting w-r interaction



High pressure wing edge; v. high pressure nose; repeated impact load

Observing & predicting w-r interaction

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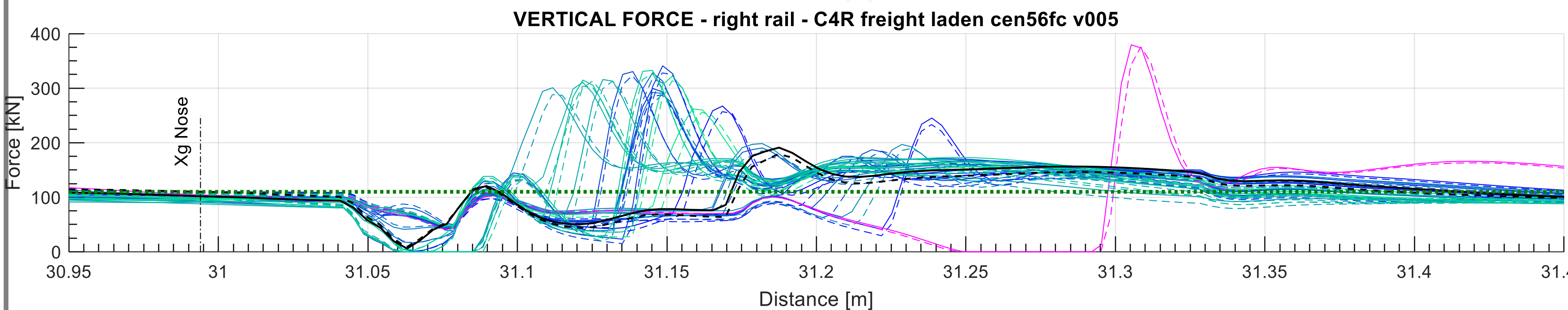
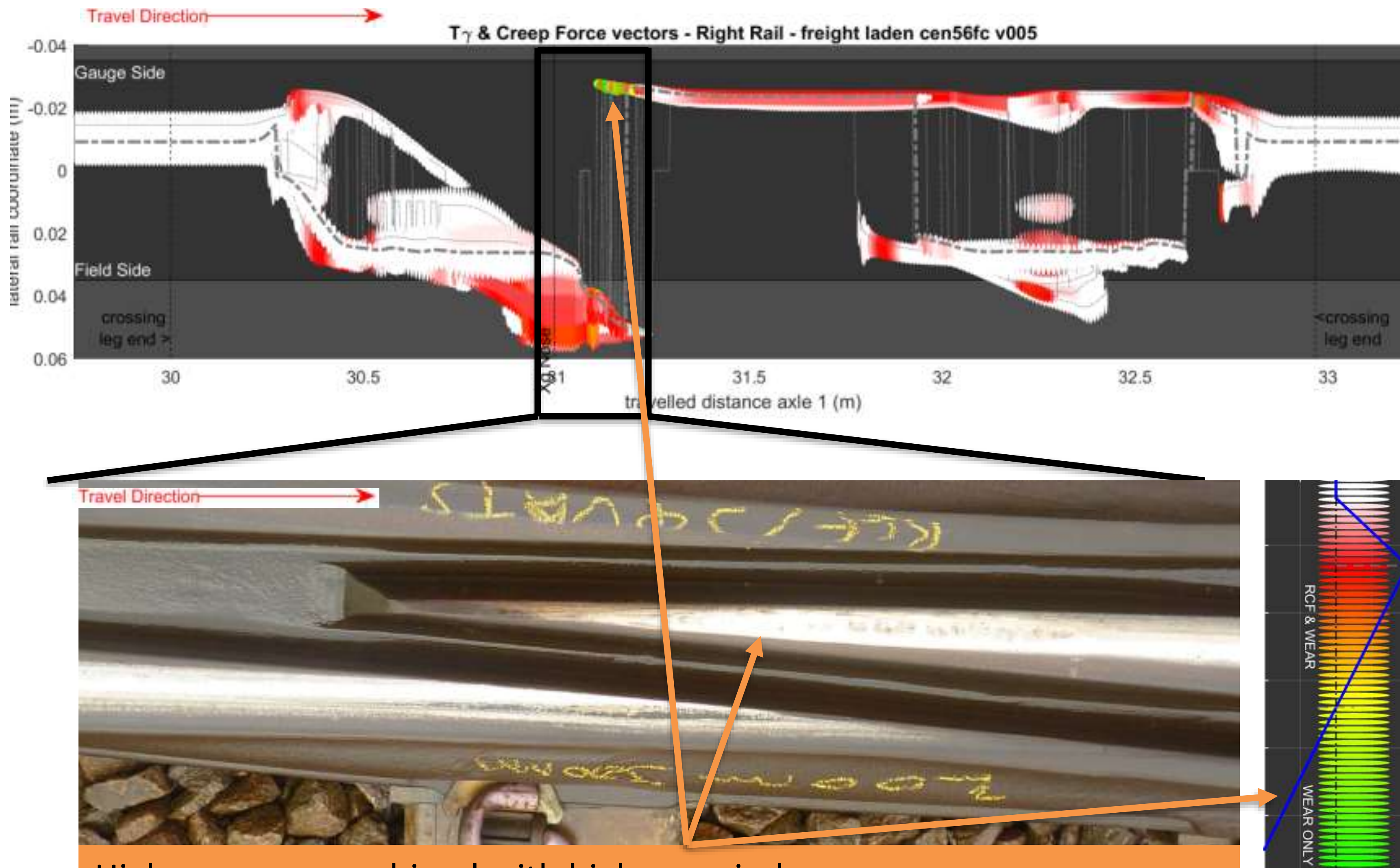


Squats marks corresponding to peak P1 pressure and overall high pressure deformed profiles over P2 action zone

Observing & predicting w-r interaction

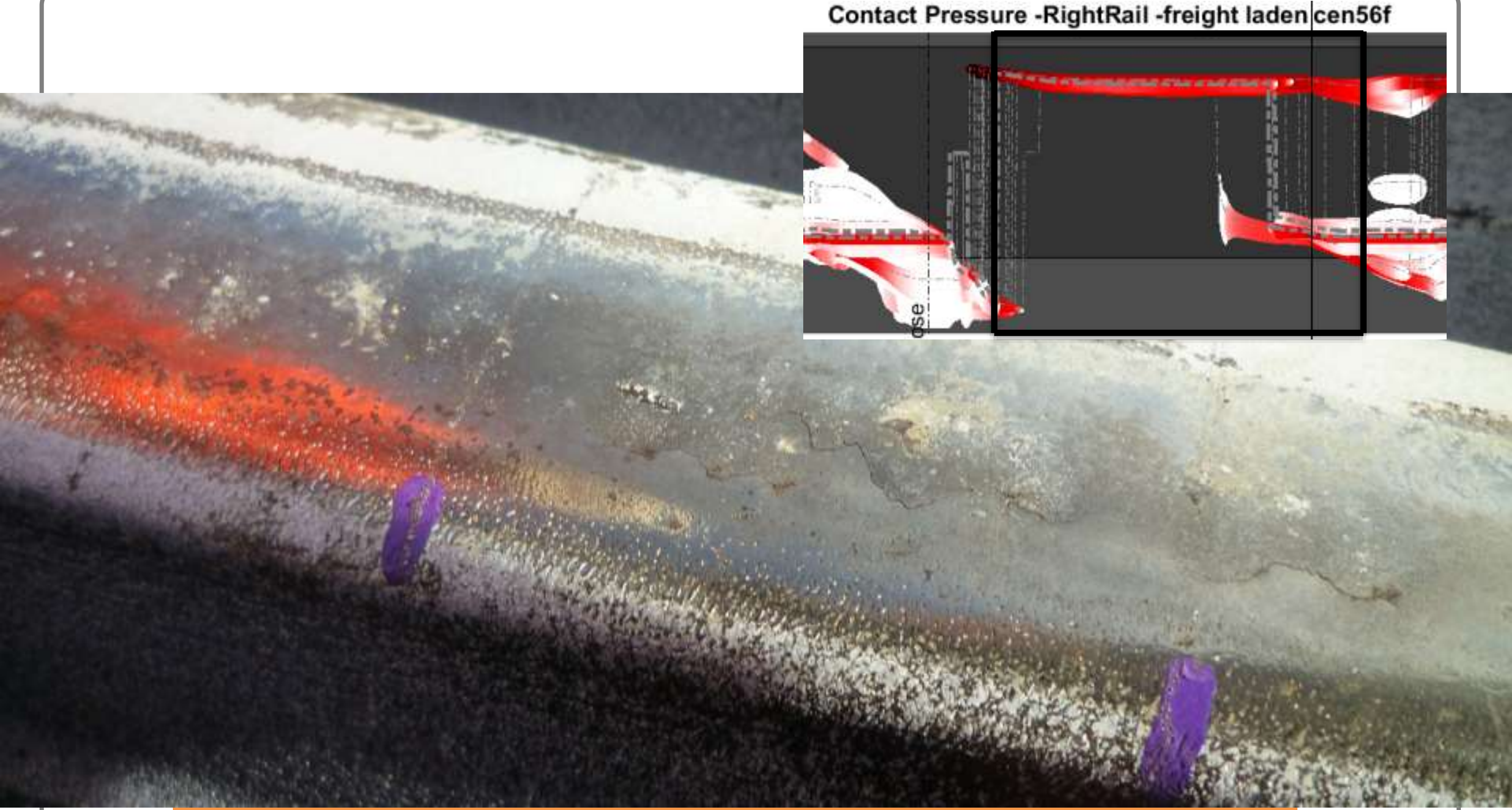


High pressure combined with high wear index on nose

Observing & predicting w-r interaction

High pressure combined with high wear index on nose

Observing & predicting w-r interaction



RCF initiation on crossing vee

4) Assessing the benefits of innovations

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Assessment of new crossing geometry

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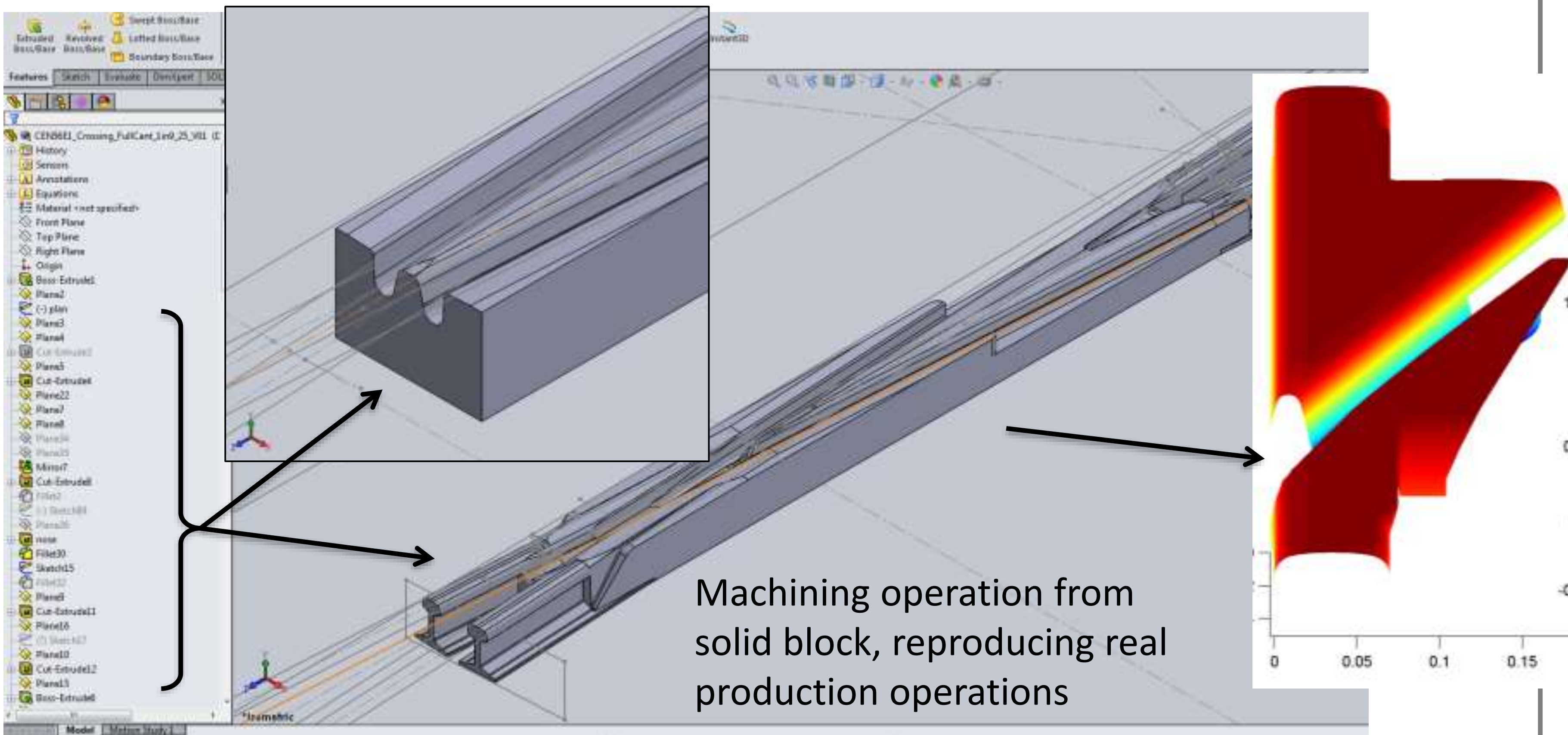

Machining operation from solid block, reproducing real production operations

Comparative study of 4 different UK crossing designs in use: CEN56 vertical and inclined, NR60 existing and improved

Assessment of new crossing geometry

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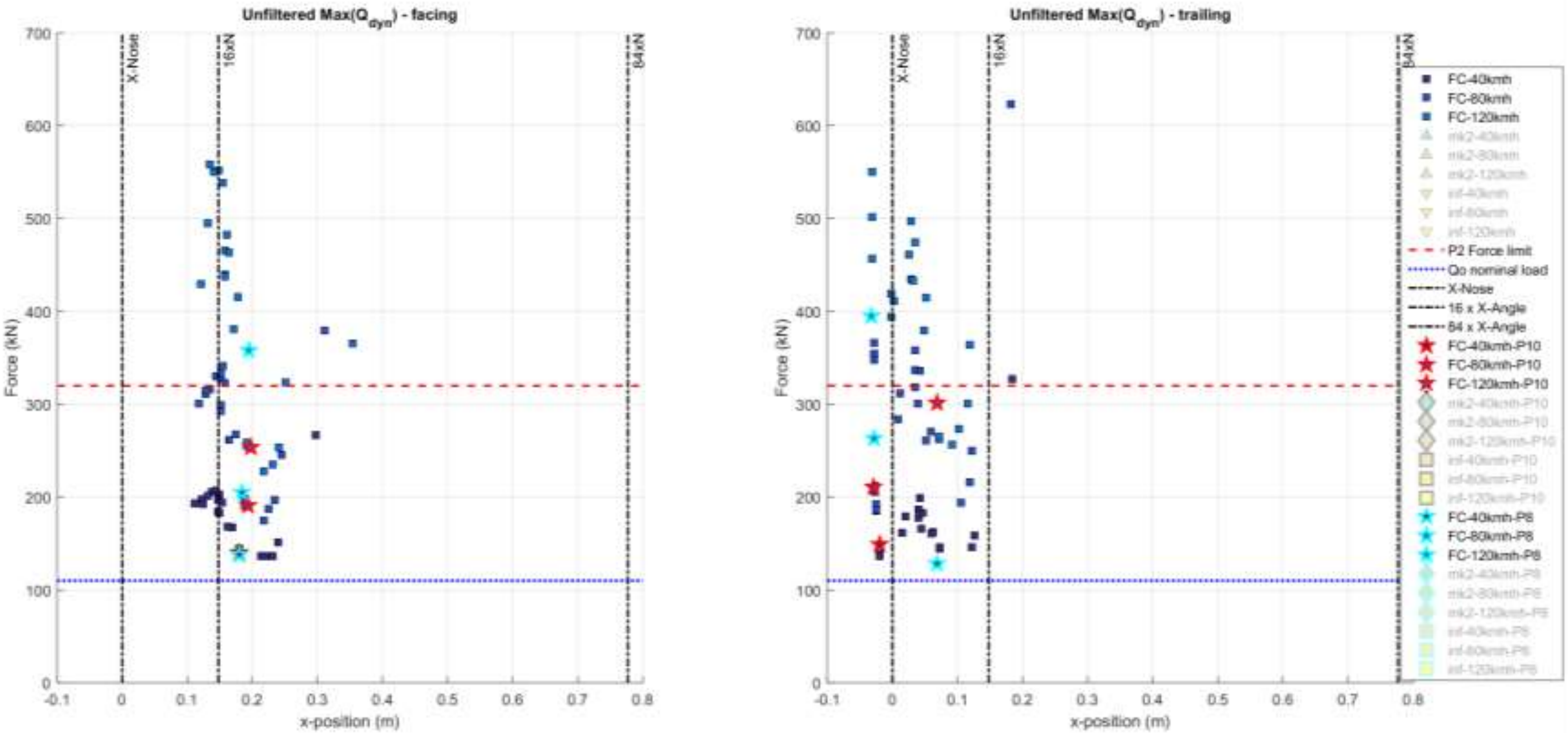

P1 vs load transfer position - CEN56fc

Assessment of new crossing geometry

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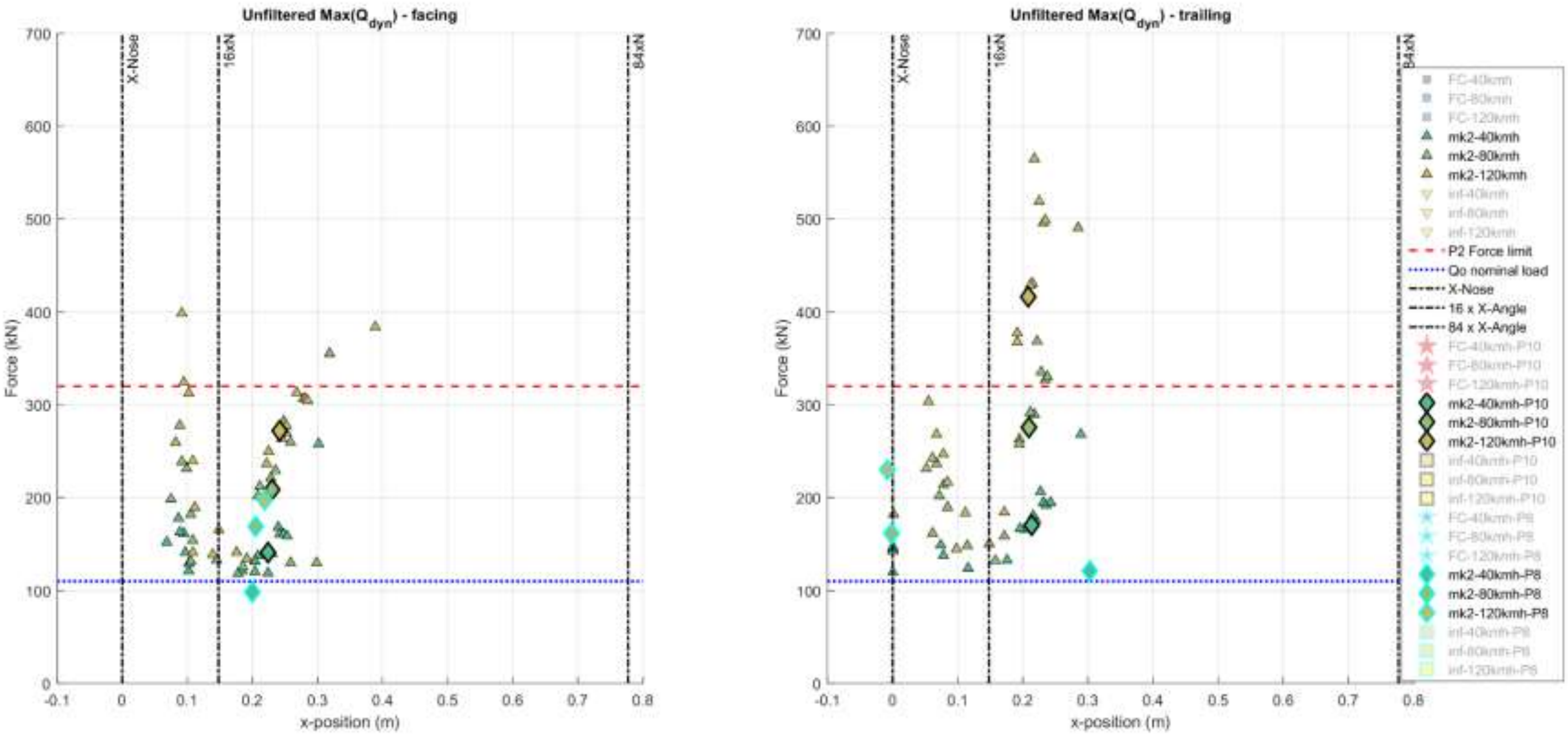
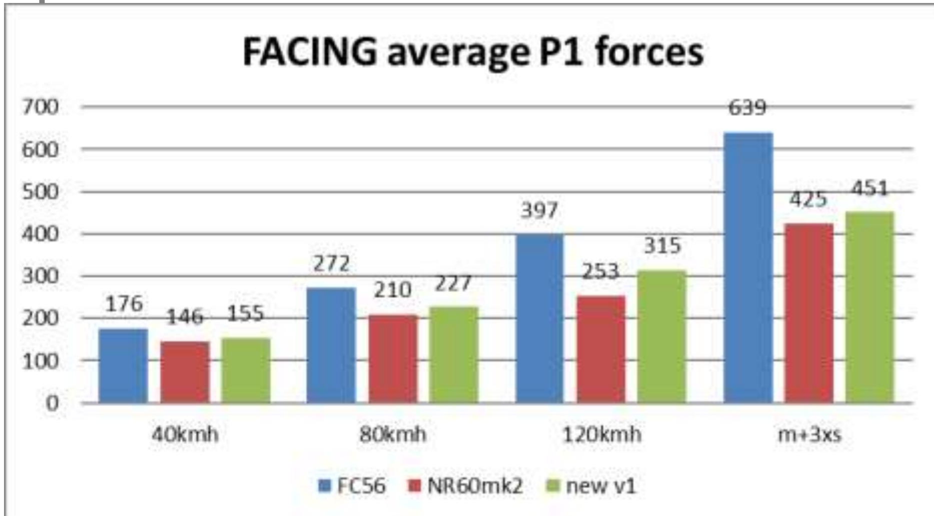
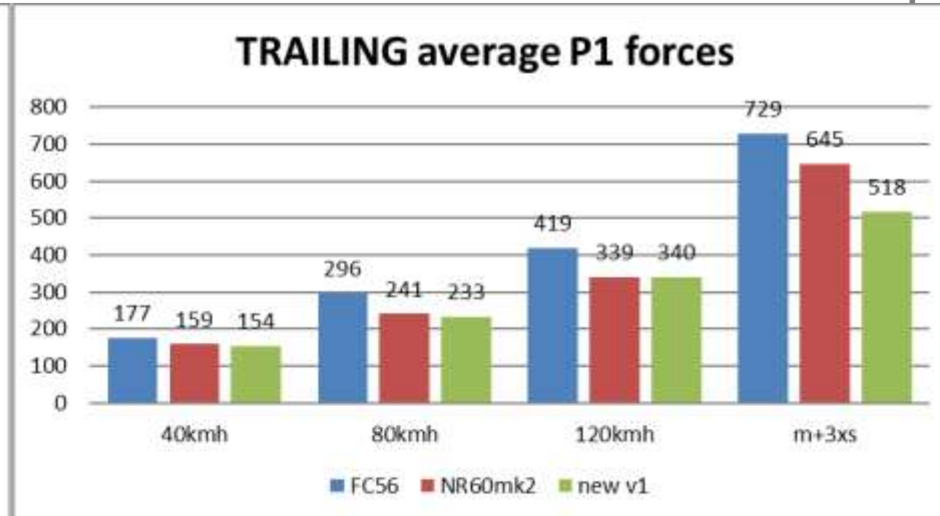


P1 vs load transfer position - NR60

Assessment of new crossing geometry





	FACING	average P1 forces		TRAILING	average P1 forces	
	FC56	NR60mk2	new v1	FC56	NR60mk2	new v1
40kmh	0%	-17%	-12%	0%	-10%	-13%
80kmh	0%	-23%	-17%	0%	-19%	-21%
120kmh	0%	-36%	-21%	0%	-19%	-19%
average	0%	-28%	-18%	0%	-17%	-19%
SD	0%	-38%	-39%	0%	-8%	-36%
$\mu+3x\sigma$	0%	-33%	-29%	0%	-12%	-29%

Opportunities for innovation

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- Geometry
  - Smooth changes (avoid contact jumps) and more conformal shapes
  - Ensure compliance with a wide range of representative wheels shapes
  - Minimise dip angle (geometrical calculation)
- Support
  - Use of USP, shorter sleeper spacing, resilient baseplate systems
  - Hybrid tracks > slab track
- Materials
  - Better resisting material for nose, wing, switches
- Monitoring
  - Profile geometry measurement (at regular time intervals)
  - Geometry monitoring (alignment in switch panel)
  - Vibration analysis (finding and eliminating high damage instances)
    - Track-side
    - On-board vehicles
      - Instrumented wheelset (not high frequencies enough)
      - Axle box accelerations (need to be tuned for HF + data collection) and need to know positions of S&C

Conclusions

- S&C attract disproportionate amount of damage and costs
- Careful wheel-rail geometry interaction can significantly improve system performance from design through to continuous monitoring for sustained performance
- Support discontinuity should be ‘bridged’ using more resilient layers (baseplate on resilient pad) and better load distribution within the superstructure and support layers
- High impact load instances can be monitored and ruled out, this requires both track side and vehicle based instrumentations and intelligence
- Numerical simulation together with site observation/measurement can offer a unique view of the system interaction
- Finally, simple rules and algorithm can be derived from studies as presented here for a more direct industrial applications

Thank you for your kind attention

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Acknowledgements: