Vampire and the Permanent Way

2025

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Contents

What is railway vehicle dynamics?

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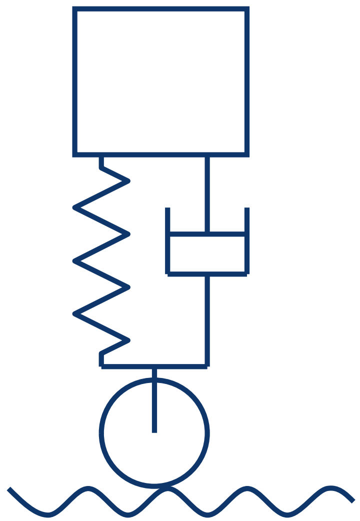
What is railway vehicle dynamics?

- Dynamics is the study of masses in motion
- Vehicle dynamics applies this to vehicles- road, rail, air, sea, space…
- Railway vehicle dynamics is distinct from other types because of the steel wheel to steel rail interface
- Covers modal frequency and damping, ride quality, derailment risk, wheel and rail wear, gauging etc.
- Complex subject, needs specialist software…



What is Vampire?

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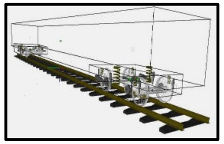
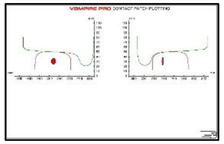
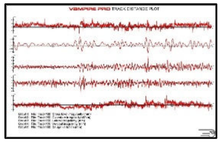
What is Vampire?



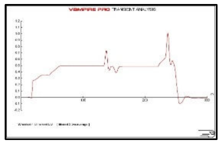
Vehicle model



wheel-rail contact



track input



outputs

- Multi-body simulation package designed for railway use
- Based on equations of motion; simplification of complex system
- Masses, inertias and centre of gravity positions for body, bogies and wheelsets
- Suspension positions and parameters for springs, dampers, anti-roll bar, bumpstops, bushes, etc.
- Different conditions: tare and laden, new and worn condition, air springs inflated and deflated

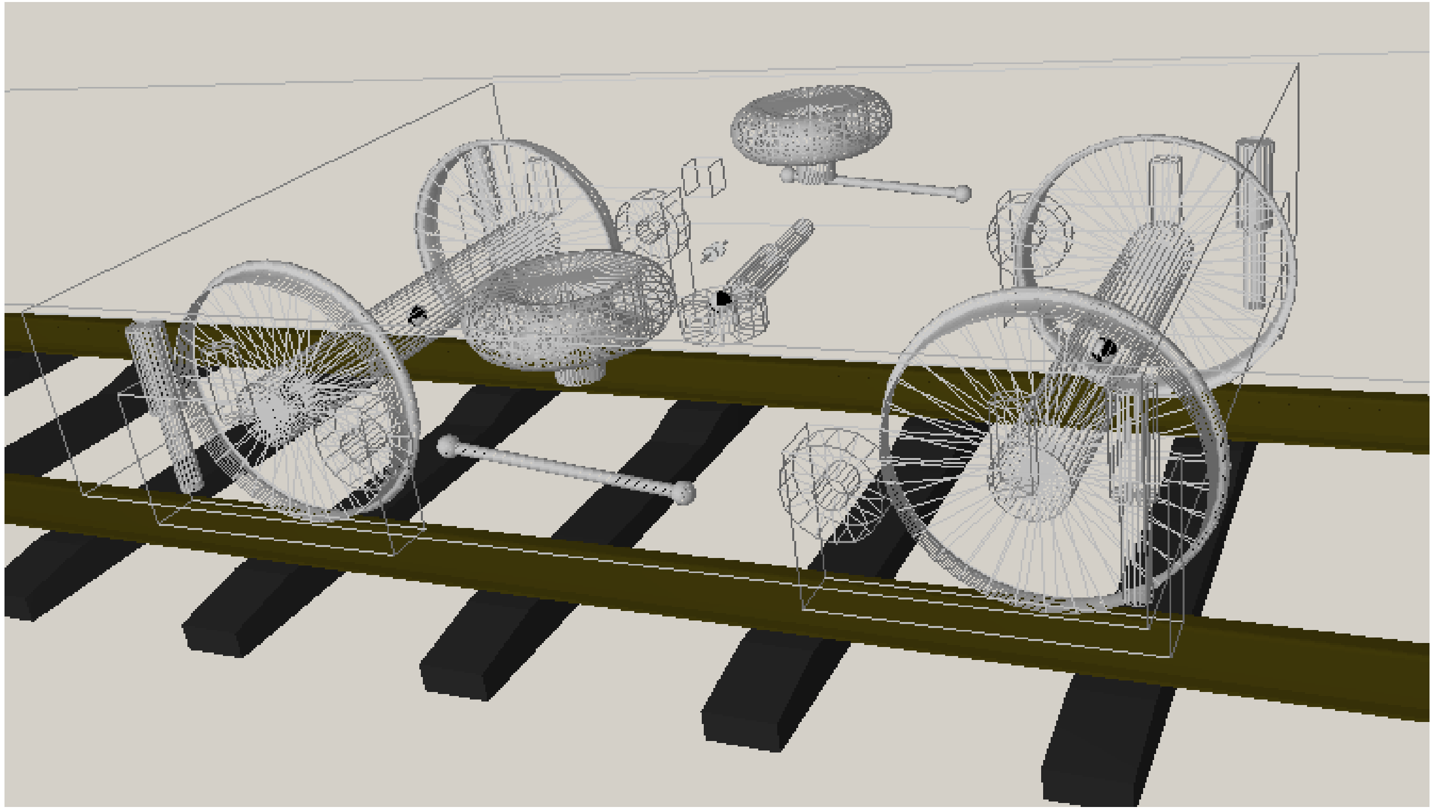
History of Vampire

- Developed as separate programs by BR Research
- Brought together as VAMPIRE® with single model format and unified front end in late 1980s
- Development continued by BR Research, AEA Technology, DeltaRail and Resonate
- Licenced to users all over the world
- Resonate decided to ‘sunset’ VAMPIRE® in 2019 and offered perpetual and developer licences and eventually an exploitation licence that would allow commercial licencing to continue
- Three exploitation licences sold- SNC-Lavalin, Oleo and ENSCO (USA)- strictly now Vampire not VAMPIRE®

History of Vampire

- Oleo has used Vampire to develop Digital Trains but apart from improved graphics, quick track modelling and dynamic arrays for larger vehicle models, has not updated the main code
- ENSCO is offering Vampire as Software as a Service (SaaS) online- not aware that they have developed the code
- SNC-Lavalin / AtkinsRéalis has added in-line contact calculation, and improved line elements and is about to release integration of advanced CONTACT model and cloud licencing
- We have also provided a free restricted version to participants in the IMechE Railway Challenge- 11 teams now have Vampire

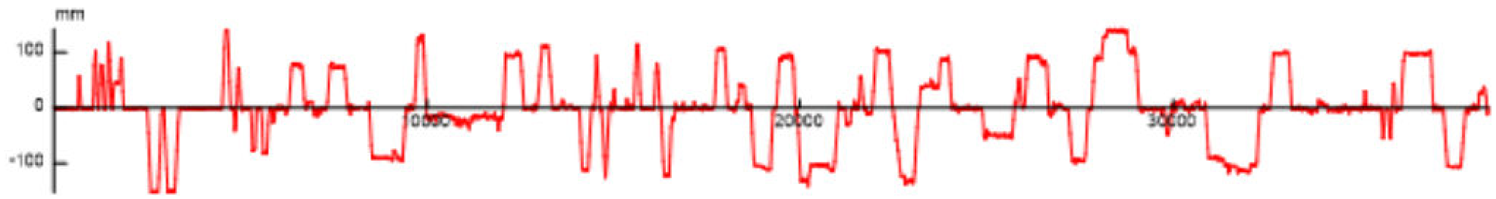
A typical Vampire model (bogie detail)



Rolling stock dynamics simulation with Vampire

Examples of inputs:

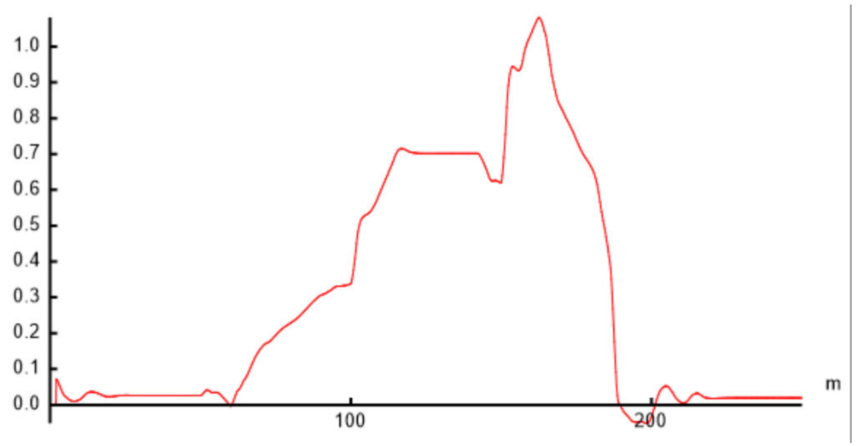
- Track design geometry and irregularity- discussed later
- Traction and braking forces at the wheelsets
- External forces such as wind loading or inter-vehicle forces



Rolling stock dynamics simulation with Vampire

Examples of outputs:

- Body accelerations and displacements
- Suspension component forces and displacements
- Bogie accelerations and force inputs
- Wheel-rail forces
- Safety against derailment outputs for wheel unloading, flange-climbing (Y/Q) and roll-over



Vampire vs Track-Ex

- Track-Ex is a Network Rail (NR) developed track management tool
- Developed to provide wider access within NR to Vampire type outputs for wear and Rolling Contact Fatigue (RCF) (and reduce cost of licensing Vampire)
- Produces approximate wear and RCF damage predictions based on:
  - Track geometry, including short wavelength alignment
  - Vehicle Damage Matrices (VDMs), which are look-up tables of Vampire quasi-static curving simulation results for different vehicles and conditions
  - Algorithms to approximate dynamic damage based on track alignment (irregularity)
- Provides a good approximation, but cannot give the same detail as a full dynamic simulation with Vampire – for example vehicle and wheel/rail interface changes cannot be considered

Why use Vampire for Permanent Way projects?

Can predict parameters that are affected by track design such as:

- Forces on track and individual rails
- Risk of rail wear and RCF
- Effect of flange lubrication
- Derailment risk, need for check rails
- Rate of change of cant deficiency
- Passenger comfort

Allows track design to be optimised in terms of vehicle / track interaction

How does Vampire model the permanent way?

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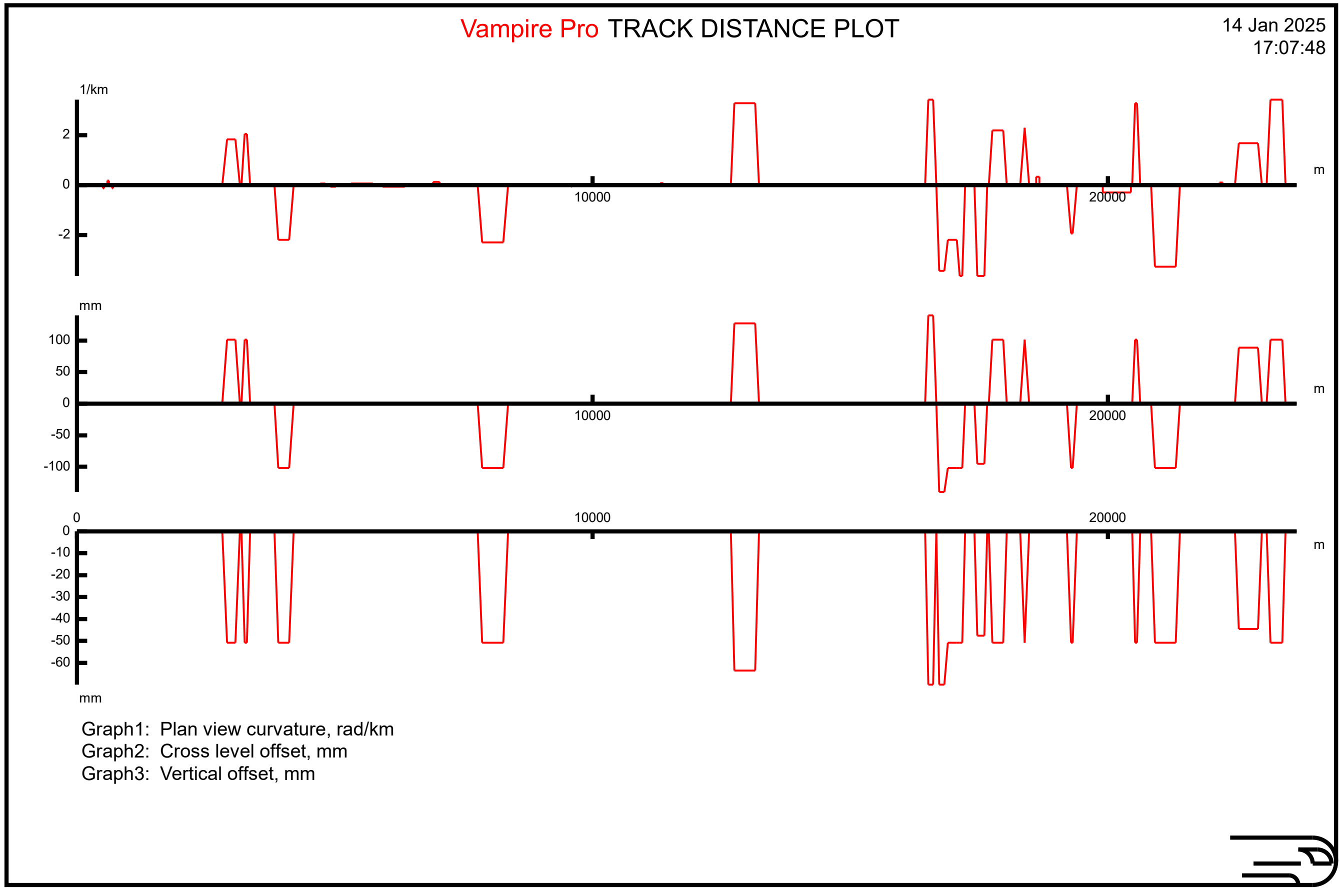
Geometry- Vampire Track Design file

- Models track design geometry
- Usually created manually to model curves, gradients etc.
- Channels are:
  - Curvature
  - Vertical offset
  - Cross-level
  - Kink
  - Speed
- Units can be metric or imperial (English)

Geometry- Vampire Track Design file

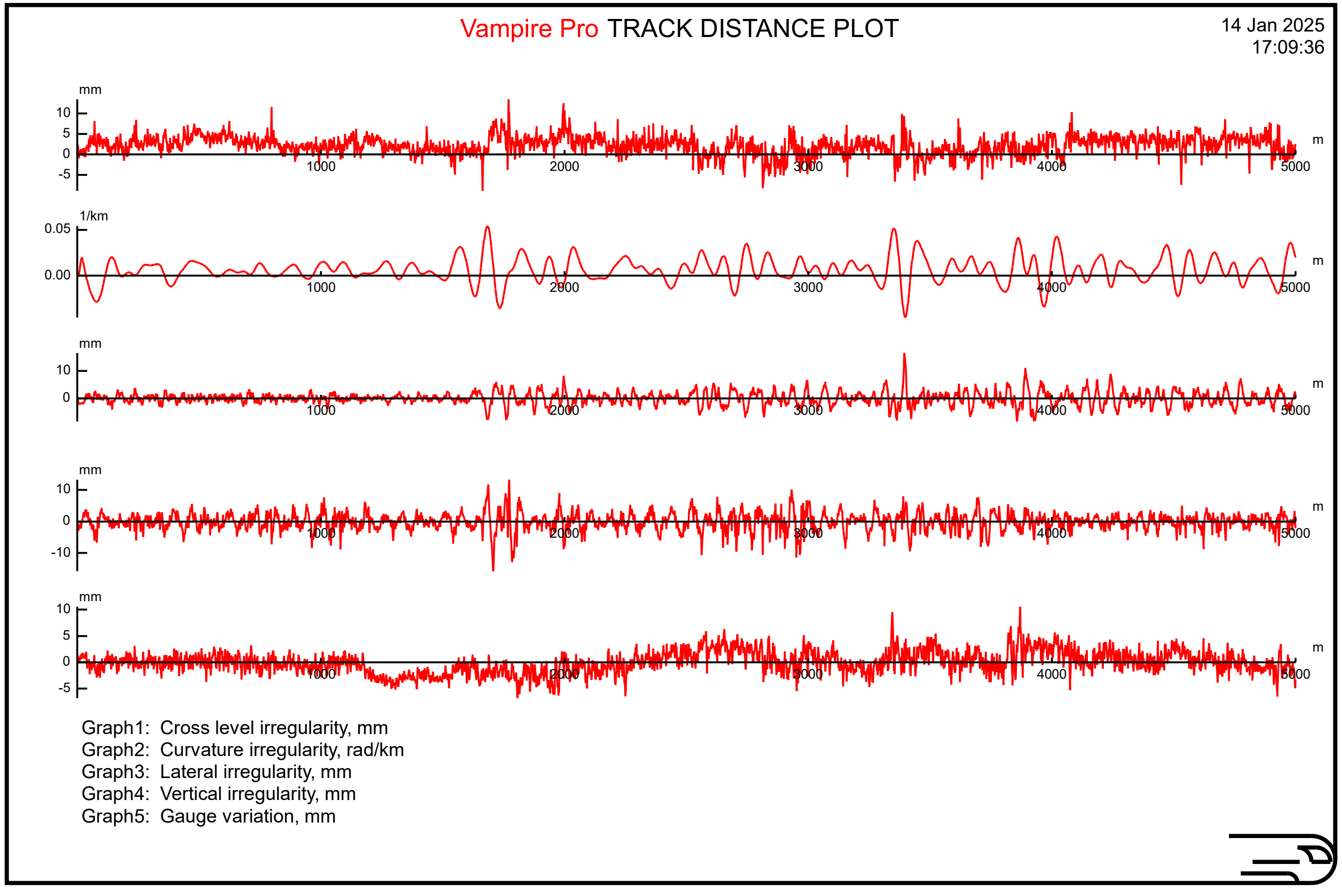


Vampire Plot

Geometry- Vampire Track Irregularity file

- Models track design or measured geometry (e.g. New Measurement Train)
- Usually created from track recordings but can be manual
- Channels are:
  - Cross-level
  - Curvature
  - Lateral irregularity
  - Vertical irregularity
  - Gauge variation
- Units can be metric or imperial (English)

Geometry- Vampire Track Irregularity file



Vampire Plot

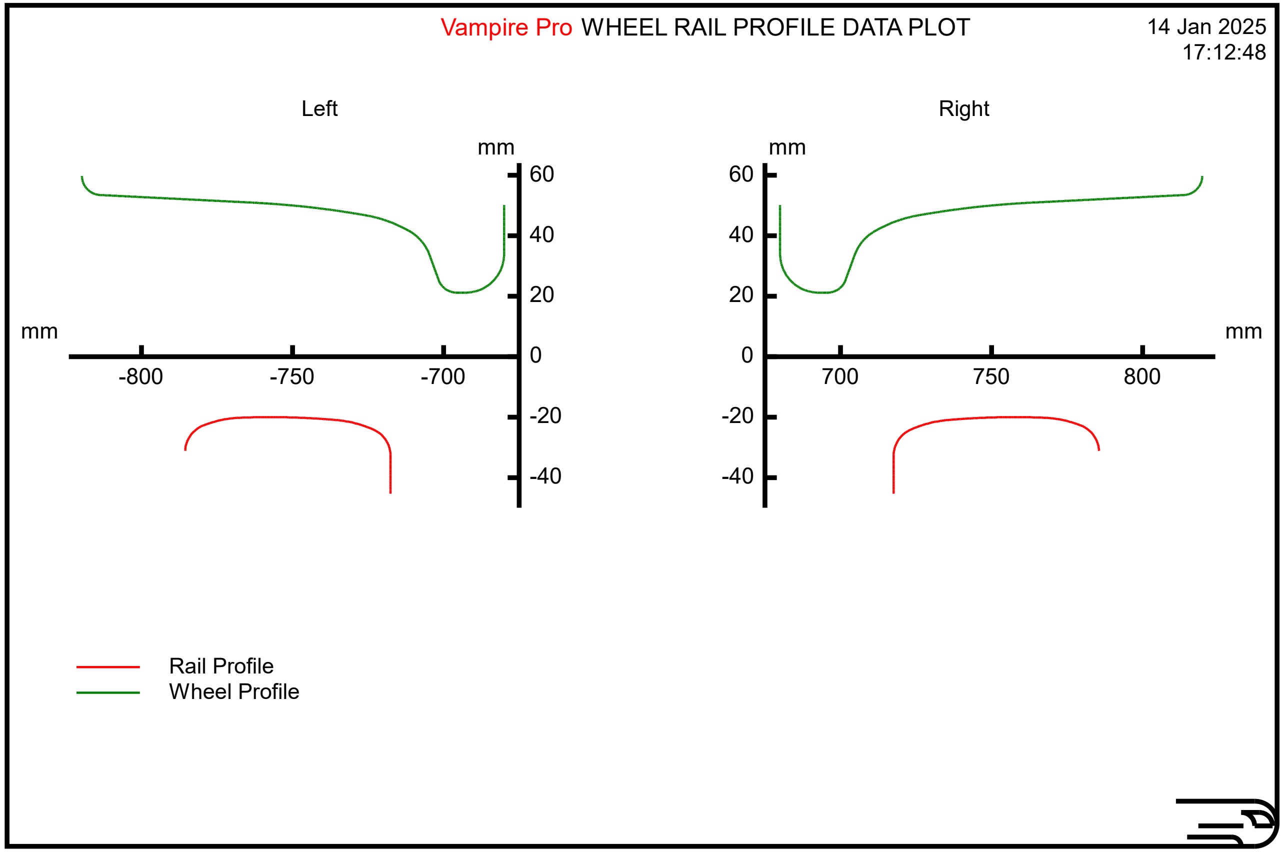
Geometry- additional features

- Design and Irregularity files can also model check rails
- Newer csv format files can also contain IGNORE channels for additional reference information (e.g. ELR and track ID)
- Separate Vehicle Speed file avoids interpolation needed in Design file

Wheel and rail profiles- Vampire and MiniProf formats

- Vampire wheel profile files (.whe) include Y-Z co-ordinates for both wheels
- MiniProf wheel profile files (.whl) include Y-Z co-ordinates for one wheel
- Vampire rail profile files (.rai) include Y-Z co-ordinates for both rails
- MiniProf rail profile files (.ban) include Y-Z co-ordinates for one rail
- Profiles can be measured using MiniProf or Calipri or created from MiniProf templates or using Excel or CAD

Wheel and rail profiles- Vampire and MiniProf formats

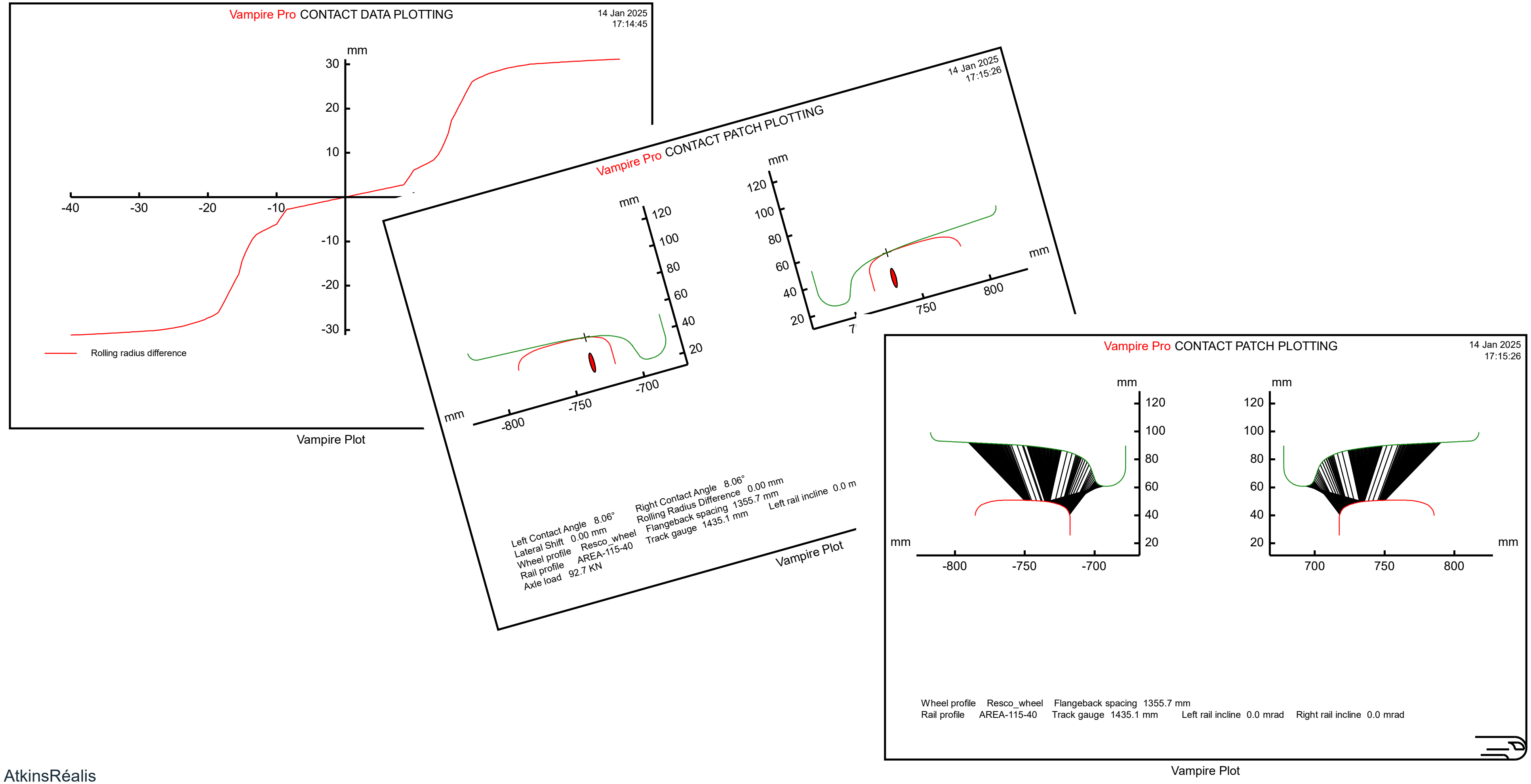


Vampire Plot

Wheel and rail profiles- Contact Data files

- Vampire combines wheel and rail profiles to create contact data
- Need gauge, wheel diameter and axle load
- Tabulates contact positions, angles, rolling radii, contact patch area and ellipticity etc. for each wheel / rail lateral shift
- Used during transient simulations making them very fast
- Can use different contact data for different wheelsets if profiles, loads or wheel diameters are significantly different
- Can vary contact data along the track if rail profile varies, especially for planed sections of switches- uses a Track Contact file

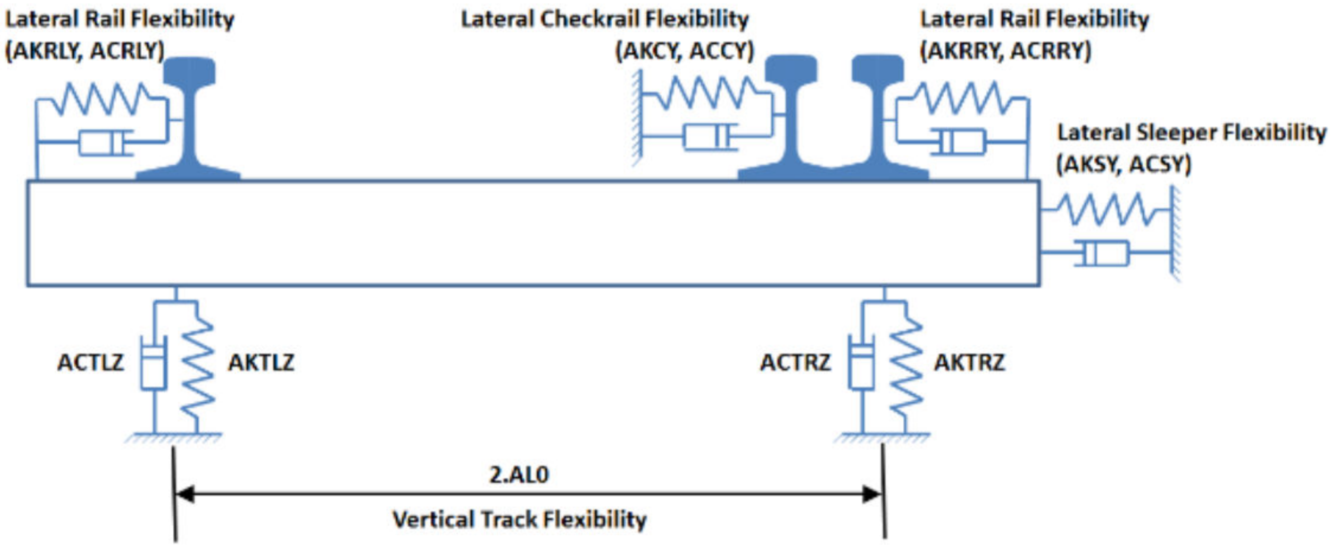
Wheel and rail profiles- Contact Data files



Wheel and rail profiles- in-line contact data

- For ultimate accuracy can create contact data at every time step
- Much slower than using precalculated data but useful for detailed simulations over short distances
- Will soon include the advanced CONTACT model from V-Tech

Track stiffness and damping



- Vampire uses default values but these can be varied
- Can change for whole simulation or vary along the track (e.g. different track forms or wet spots) using a Track Parameter file
- Can also change wheel / rail friction along the track

Case study 1- Levenmouth Link

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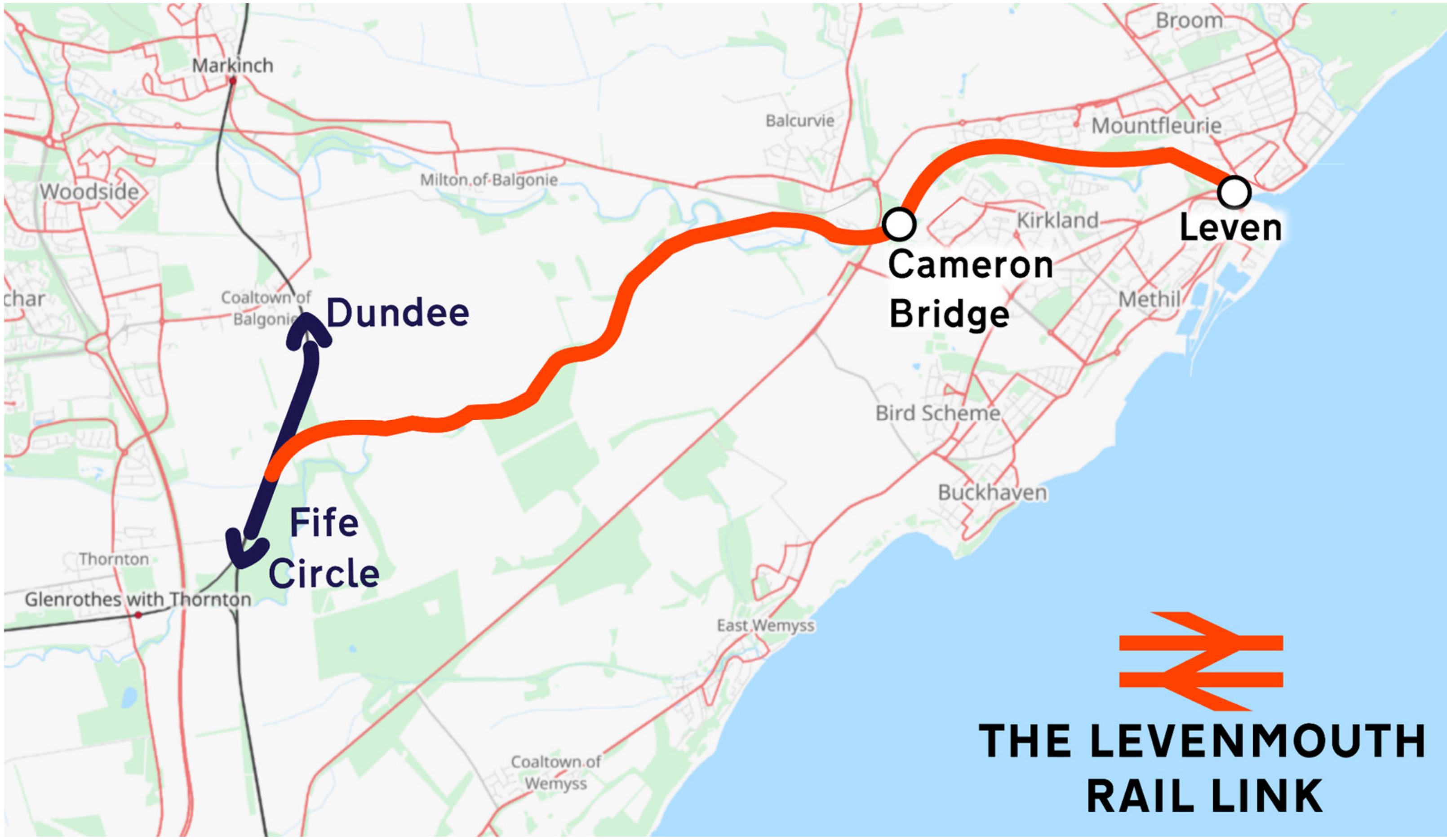
Case study 1- Levenmouth Link project

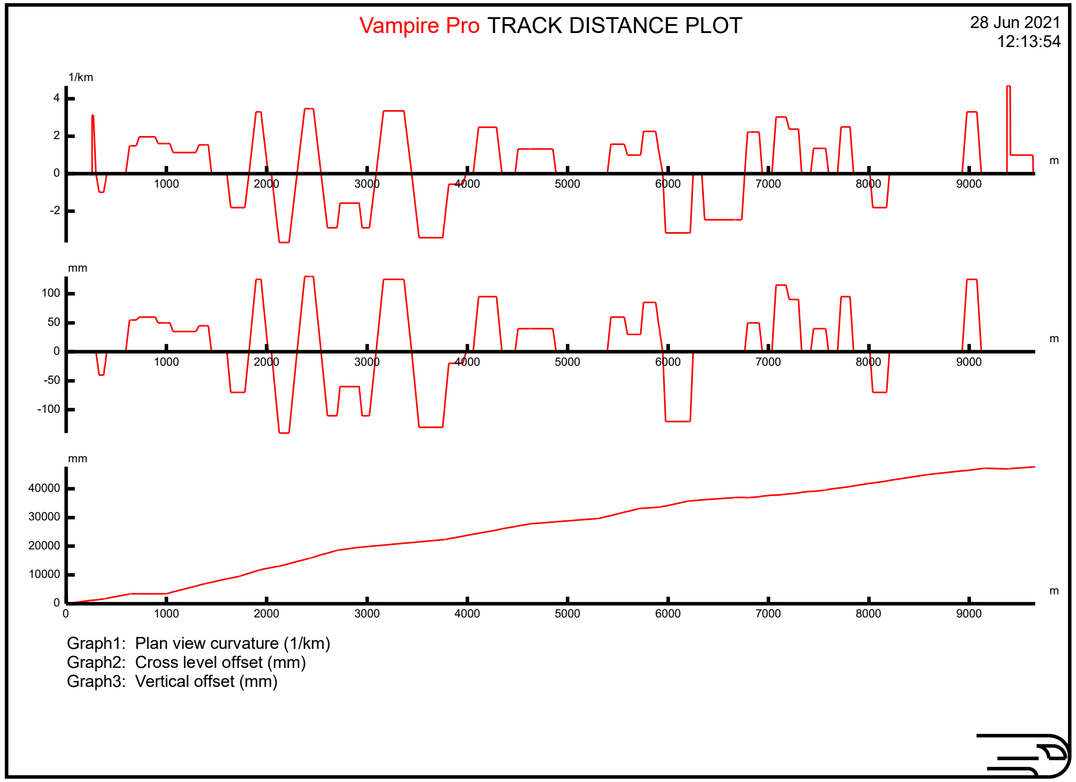


Case study 1- Levenmouth Link project

- 5 mile branch line from Thornton North Junction to Leven in Fife, Scotland, reopened in June 2024
- Vampire dynamic simulation software used to model track geometry for the whole link
- Able to show improvement in cant excess and twist from Version 4 design to Version 5

Case study 1- Levenmouth Link project

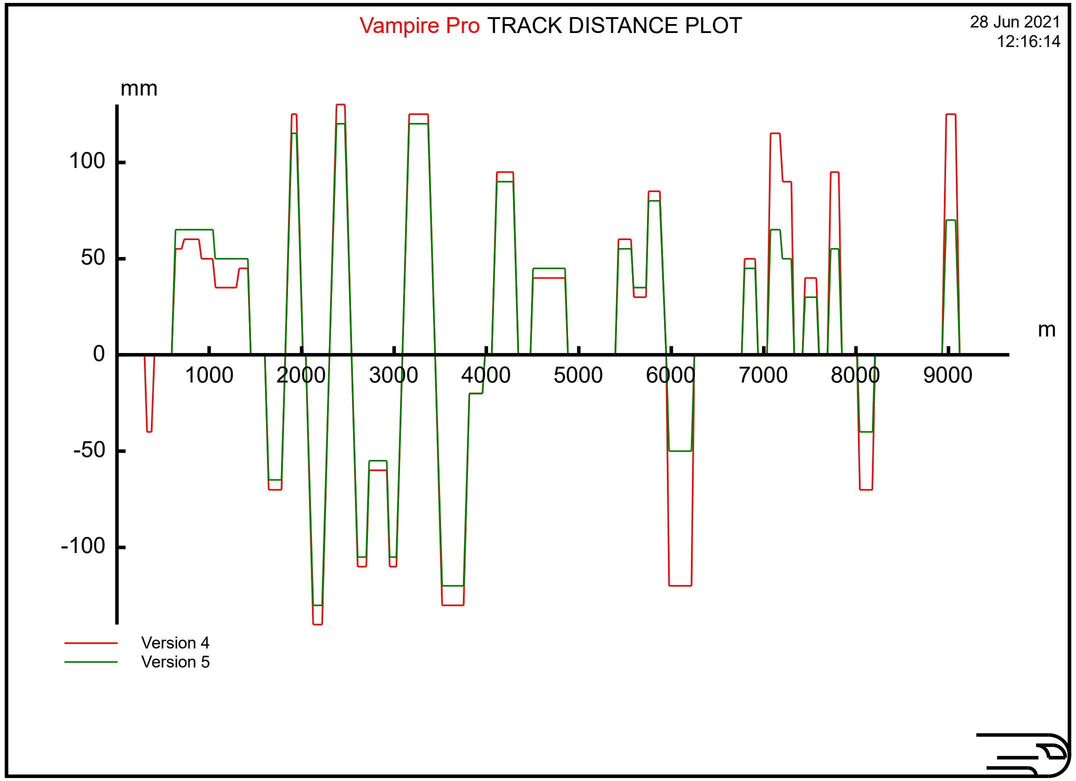
Down line track model, Version 5



Levenmouth Ling Down line

Case study 1- Levenmouth Link project

Comparison of Down line cross level, Version 5 vs. Version 4



Levenmouth Ling Down line cross level

Case study 1- Levenmouth Link project

Simulations cover:

- Class 66 freight locomotive
- Class 156 DMU
- Class 380 EMU as the link is planned to be electrified
- Y25 bogie container wagon, empty and loaded

Case study 1- Levenmouth Link project

Simulations predict:

- Cant excess and deficiency at chosen speeds
- Rate of change of cant deficiency
- Derailment risk (delta Q/Q, Y/Q and flange climb)
- Track shifting and gauge spreading forces on curves
- Wheel and rail wear numbers

Case study 1- Levenmouth Link project

- Study carried out into effect of check rails
- For curves between 200 and 300 m radius a risk assessment is needed
- Can be done using Vampire
- Preliminary simulations show derailment risk is low so check rails not needed
- Can also predict energy dissipated due to check rail contact

Case study 1- Levenmouth Link project

Future possibilities for dynamic simulation:

- Rapid assessment of the effect of track design changes on derailment risk, track forces etc.
- Optimisation of line speed
- Energy calculations
- More vehicle types could be included

Case study 1- Levenmouth Link project

Benefits to project:

- Confirmation of improvement in track design from Version 4 to Version 5 in terms of vehicle / track interaction
- Evidence for check rail risk assessment (required for radii between 200 and 300 m) showed check rails not needed- major cost saving

Case study 2- Duddeston Junction

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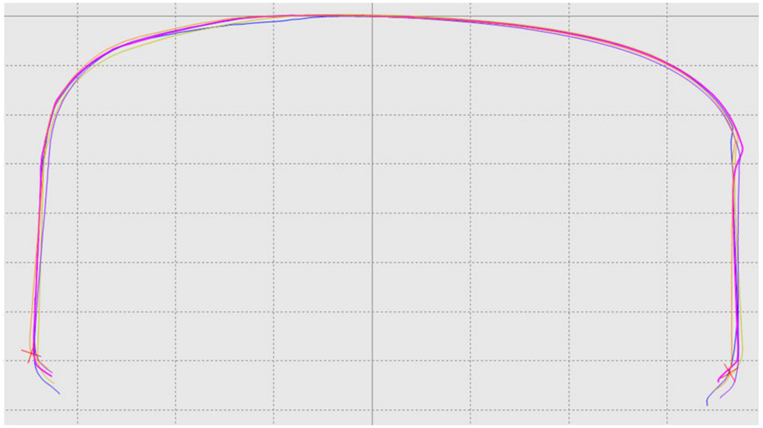
Case study 2- Duddeston Junction

Source: https://www.networkrailmediacentre.co.uk/news/railway-reopened-after-major-track-work-in-birmingham-to-improve-journeys-and-prepare-for-hs2

Case study 2- Duddeston Junction

- 500 metres of re-aligned track showing severe wear, lipping and RCF.
- Vampire dynamic simulation software used to model track geometry for the re-aligned track.
- Site visit carried out to observe and measure worn rail profiles.



Case study 2- Duddeston Junction

Simulations carried out to understand effect of:

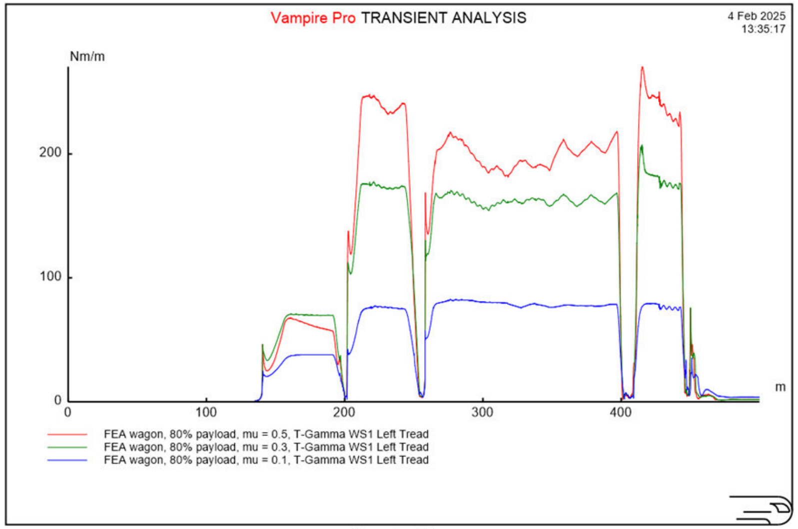
- Vehicle type: Class 66 & 3 different wagon types used.
- Load: wagons modelled at 80% and 100% of payload.
- Speed: 4 different speeds used.
- Friction: Low (0.1), medium (0.3) and high (0.5) wheel/rail friction coefficients, with and without flange lubrication.

Simulation results correlated well with on-site observations

Case study 2- Duddeston Junction

Simulations showed the following trends:

- Vehicle type: Some vehicles performed slightly better but they all showed propensity for wear and RCF.
- Load: higher loads slightly increased the amount of wear to be expected.
- Speed: not a significant factor.
- Friction: Friction was the most significant factor. Lower friction levels on both the tread and flange would decrease wear but may result in more RCF.



Vampire Plot

Case study 2- Duddeston Junction

Three recommendations made:

1. Engage with friction solution providers to investigate top-of-rail friction modifiers and flange lubrication. Benefits of this will be reduced wear.
2. Rail profiles are regularly (every 3-6 months) re-measured to determine wear rates. Benefits of this will be to predict rail life and monitor effectiveness of friction solutions.
3. Investigate cost-benefit of installing harder HP335 rails.

Recommendations are based on the principle that rail RCF can be managed by regular grinding and will benefit the project by giving a longer life than allowing rail sidewear.

Q&A

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