Using Modelling Software to Develop Wheel and Rail Profiles and Maintenance Plans

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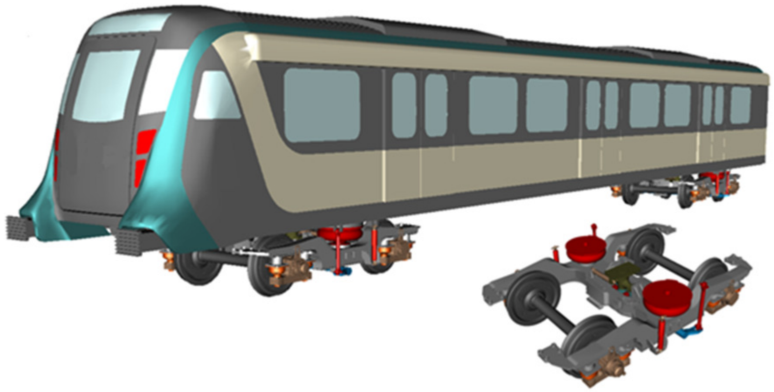
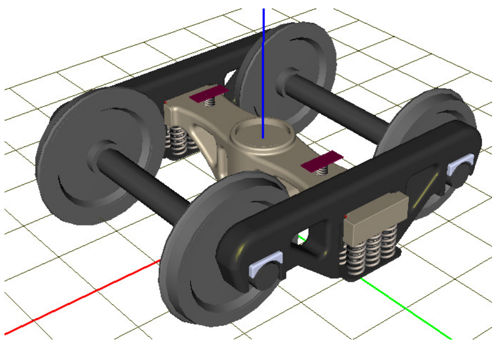
Agenda

- Monash IRT Intro
- Why Simulation?
- Simulation Packages and Process
- Testing & Validation
- Input Variables
- Simulation Output
- Case Study





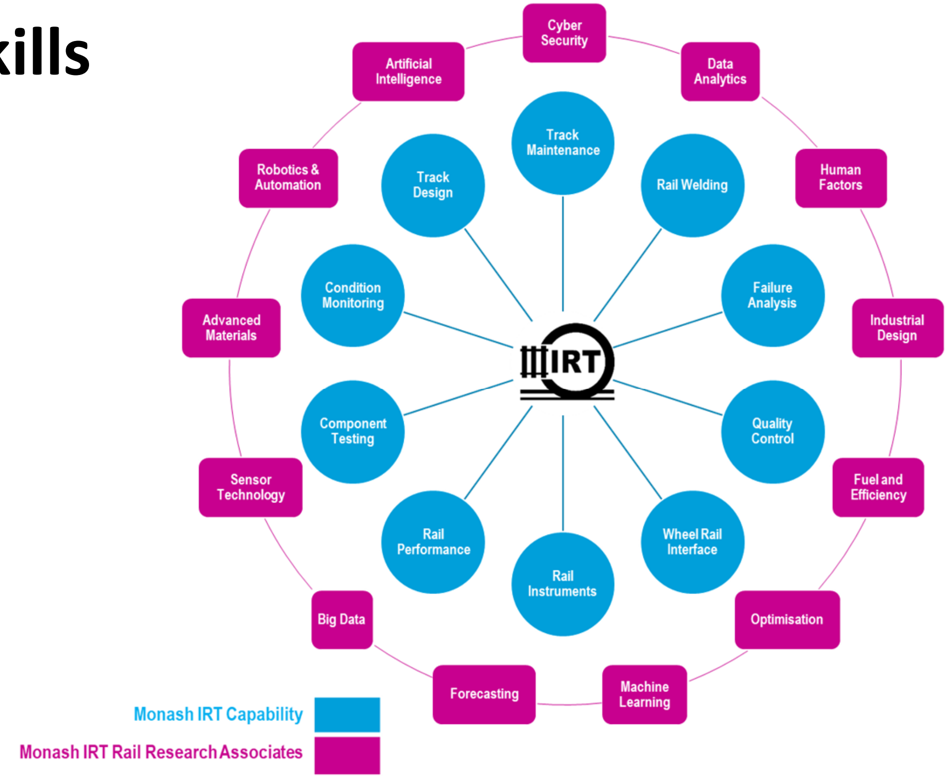
IRT Capabilities

- Materials Analysis and Physical Testing
- Condition Monitoring
- Data Analytics
- Wheel-Rail Interface
- Vehicle Dynamic Simulation
- Track Performance
- Welding Process Development
- Novel Technology Implementation

IRT Services over 160 Clients

Broader Academic Capabilities

- **Links to world class academic skills in:**
  - **Accident research**
  - **Human factors**
  - **AI and Machine Learning**
  - **Sustainable Materials**
  - **Industrial Design**
  - **Robotics and Automation**



Why Use Simulation?

- **Simulation enables us to**
  - **Undertake a range of "what if" sensitivity analyses to refine designs of both vehicle and key infrastructure components**
  - **Enable extremes of the operating envelope to be evaluated safely**
  - **Provide a cost-effective alternative to full scale testing**
  - **Undertake theoretical vehicle acceptance testing**
  - **Enable aspects of vehicle behaviour to be examined that could not be done practically or economically in any other way**
  - **Test the suitability of wheel and rail profiles and help predict damage**

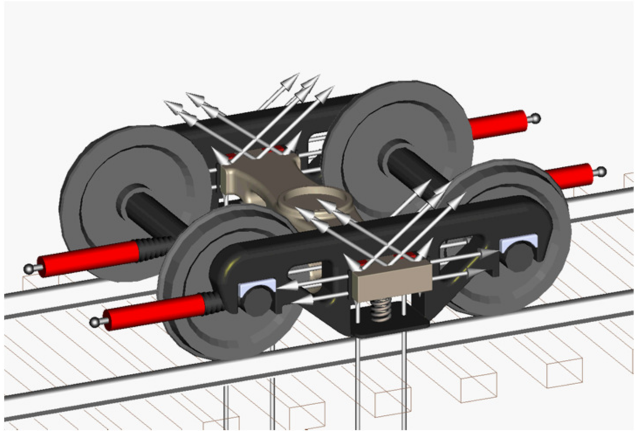
Simulation Software Packages

- **There are many. Some commonly used packages include:**
  - **Universal Mechanism (Laboratory of Computational Mechanics)**
  - **Vampire Pro (SNC-Lavalin)**
  - **NUCARS® (MxV Rail)**
  - **SIMPACK (BS Dassault Systèmes)**
  - **GENSYS (AB DEsolver)**

General Simulation Process

Model Testing and Validation

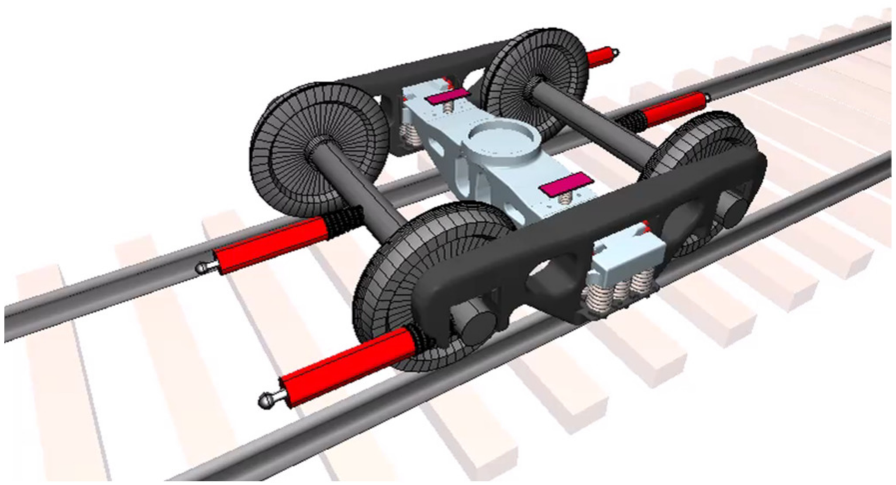
- **To obtain confidence in the output, testing and validation processes are undertaken**
  - **S-Curve negotiation**
  - **Stability tests (specified standard)**
  - **Static twist tests (Specified standard)**
  - **Warp test (3-piece bogie)**
  - **Friction wedge testing (3-piece bogie)**



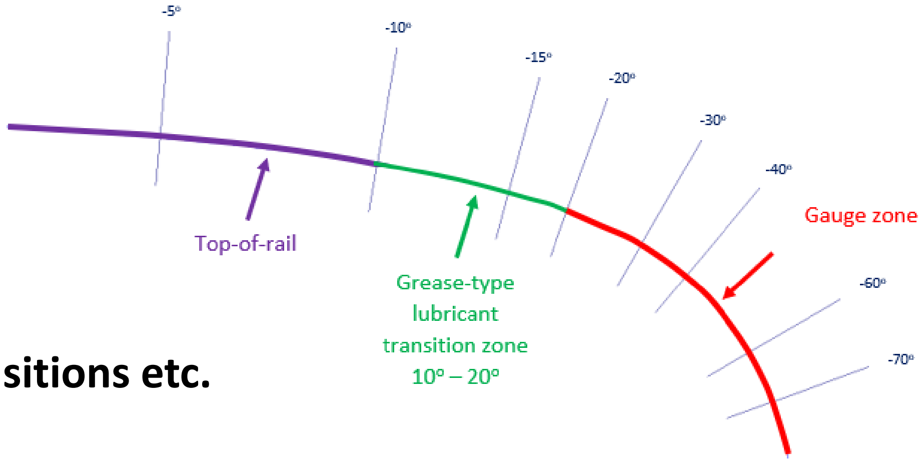
- **If measured data is available, verification may also be conducted (recommended)**

Model Testing and Validation

- **Warp test (3-piece bogie)**



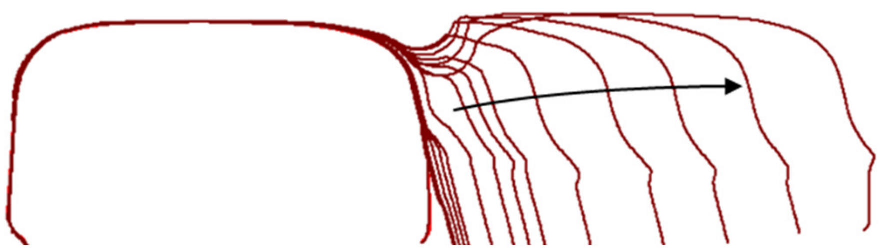
Typical Input Variables



- Vehicle speed (e.g. constant, variable)
- Friction levels
- Track gauge
- Macro geometry
  - Horizontal and vertical alignment, cant, transitions etc.
- Track irregularities
  - Transform and import from track recording vehicle
  - Develop 'worst case' combined defect sets from limits

Typical Input Variables

- **Wheel and rail profiles**
  - **Design/target profiles**
  - **Measured (e.g. with Miniprof)**
  - **Symmetric or asymmetrical**
  - **Rail profile evolution (e.g. switch rail)**



Simulation Output

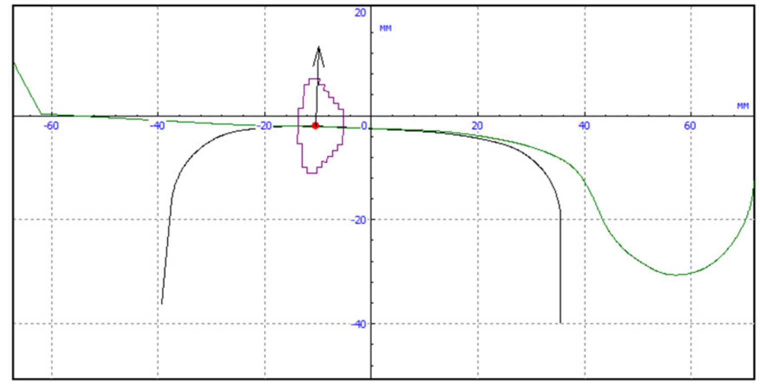
- General output parameters of interest
  - Specific energy
  - Contact forces and stresses
  - Lateral on vertical force ratio (L/V)
  - Creep forces
  - Friction utilisation
  - Wheelset angle of attack
  - Contact angle
  - Contact location
  - Contact patch details
    - Size
    - Area

Simulation Output

- Post-process to obtain more useful results in terms of
  - Damage behaviour (wear and RCF)
  - Flange climb risk
  - Wheel unloading
- Directly used in subsequent Finite Element Analysis for more detailed assessments
  - sub-surface stress, deformation and fatigue behaviours
- Wheel and rail profile modification and optimisation

Simulation Output

- **CONTACT add-on replace simplified algorithms with detailed contact algorithms**
  - **Full non-Hertzian geometry**
  - **Full linear elasticity theory**
- **Main benefits**
  - **Provide improved calculation of contact stresses, creepages and creep forces**
  - **Improved accuracy for detailed studies of wear and RCF**



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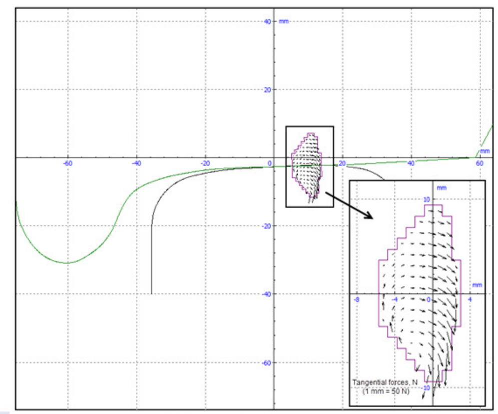
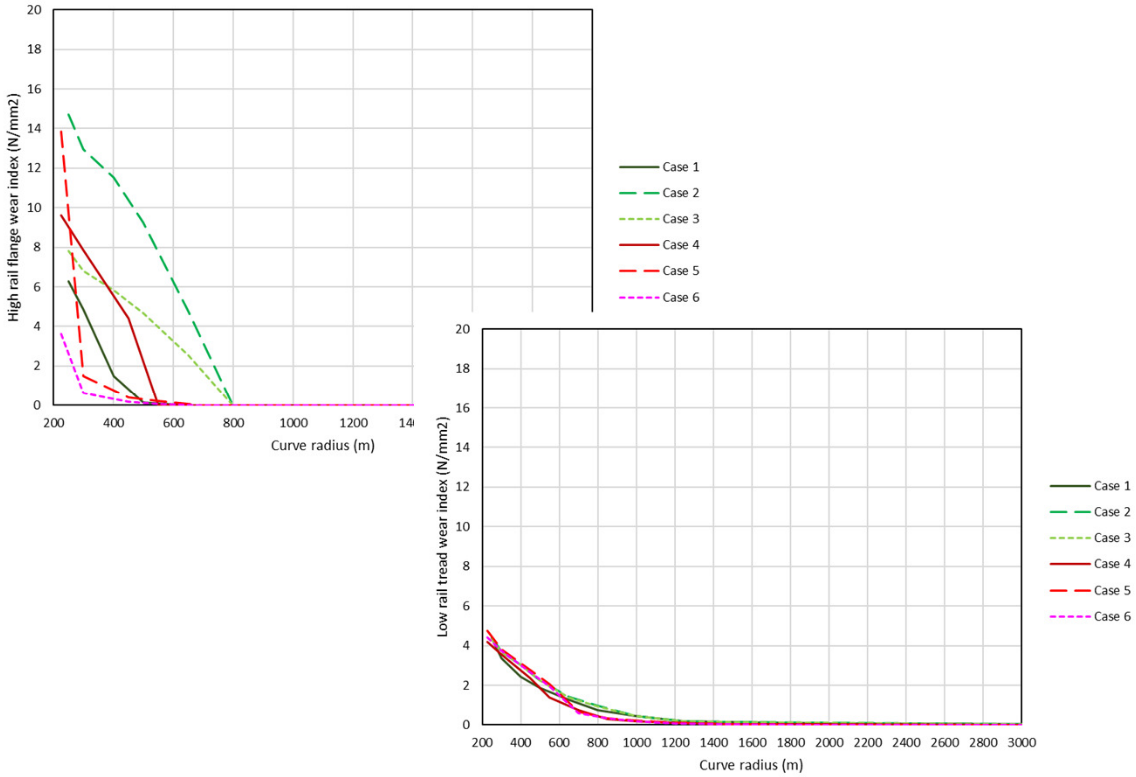


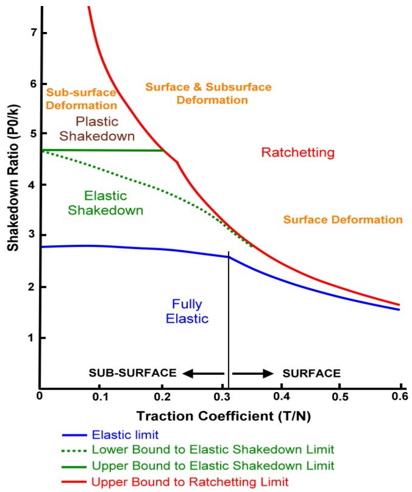
Using Simulation Output

- **Wear index**
  - **Specific energy consumed over the W/R contact area**
    - **Flange**
    - **Tread**
    - **Wheelset total**
  - **Higher the wear index value the greater the expected wear rate**

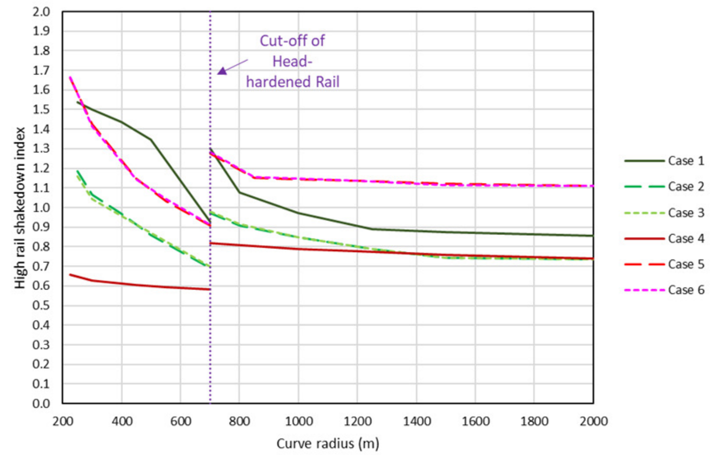


Using Simulation Output

- **Shakedown Index**
  - A normalised term of simulated shakedown ratio and theoretical shakedown limit
  - SI ≥ 1 – RCF is likely to develop
  - SI < 1 – RCF is unlikely to develop



(Johnson, 2000)



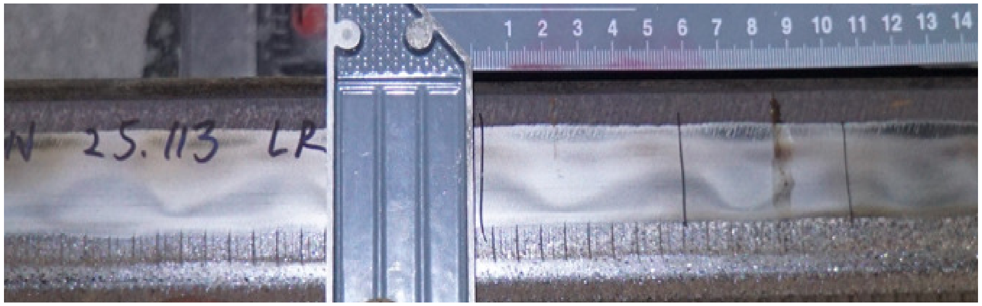
Case Study

Case Study – WRI issues on a Metro System

- Variety of track defects being noted on an asset <2 years old
- Corrugation observed on low and high rails coincidentally
- Reverse 400m curve on a hill
- RCF also present on gauge corner – primarily from transitional implementation of ground profile

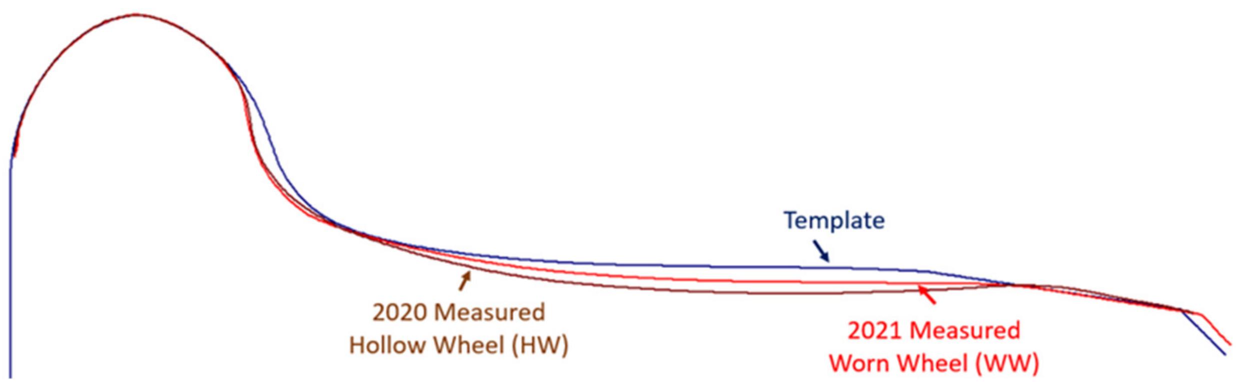
High

Low

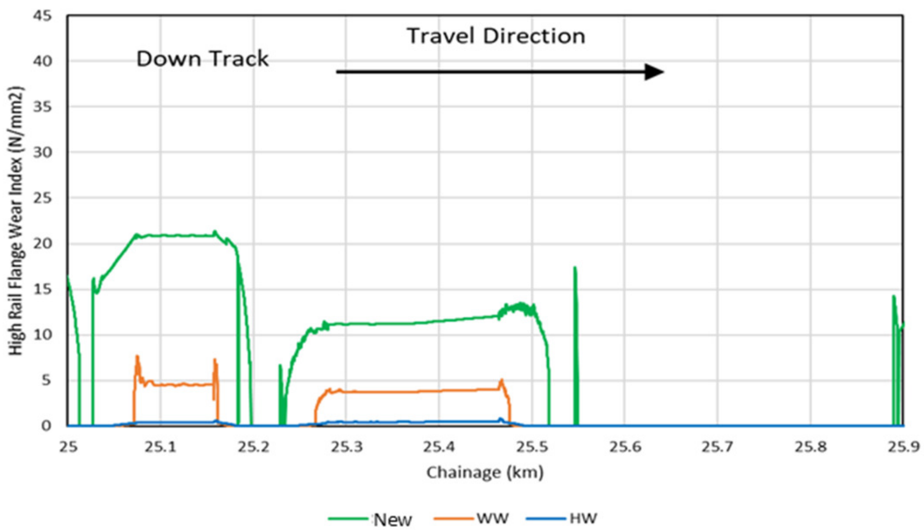


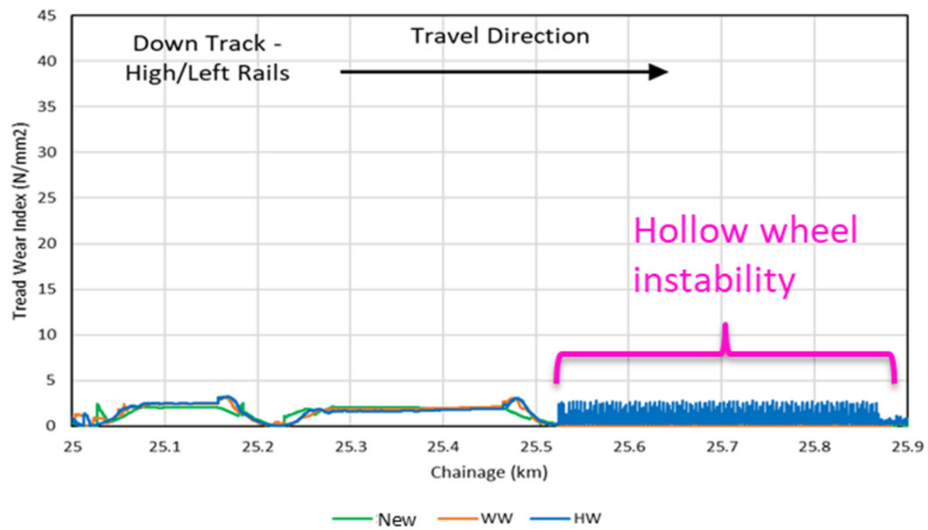
Wheels

- New wheels experiencing heavy flange penalty in early life
- Hollow then forming, leading to severe vehicle instability and vibration into cabin
- Three wheels modelled initially



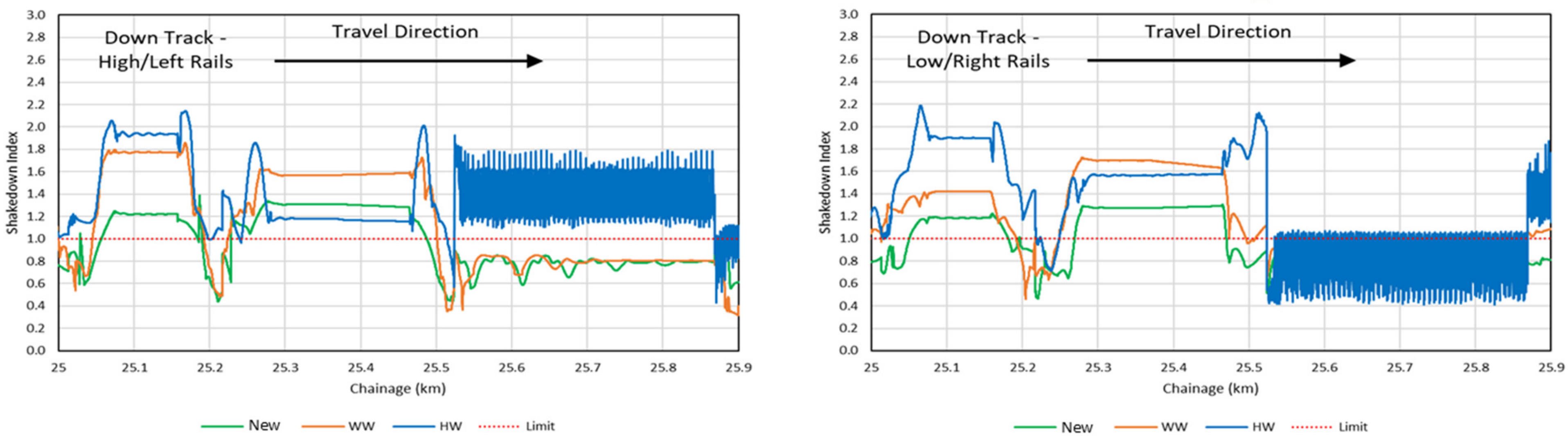
Wear Simulation Outputs





- **High rail flange wear index very high for new wheels, confirming initial flange penalty**
- **Tread wear shows instability on hollow wheel in tangent section**

Rail RCF Simulation Outputs



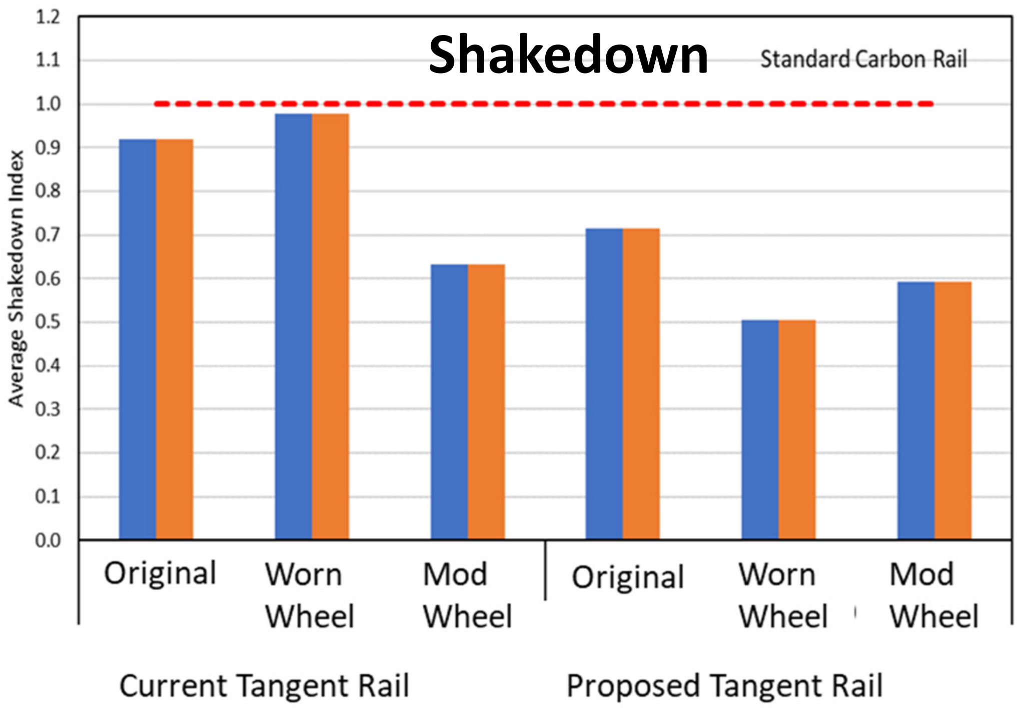
- **All wheels simulated above 1 for RCF index through curves, with instability in tangent section**
- **Combinational high wear and RCF indices indicate corrugation is likely**

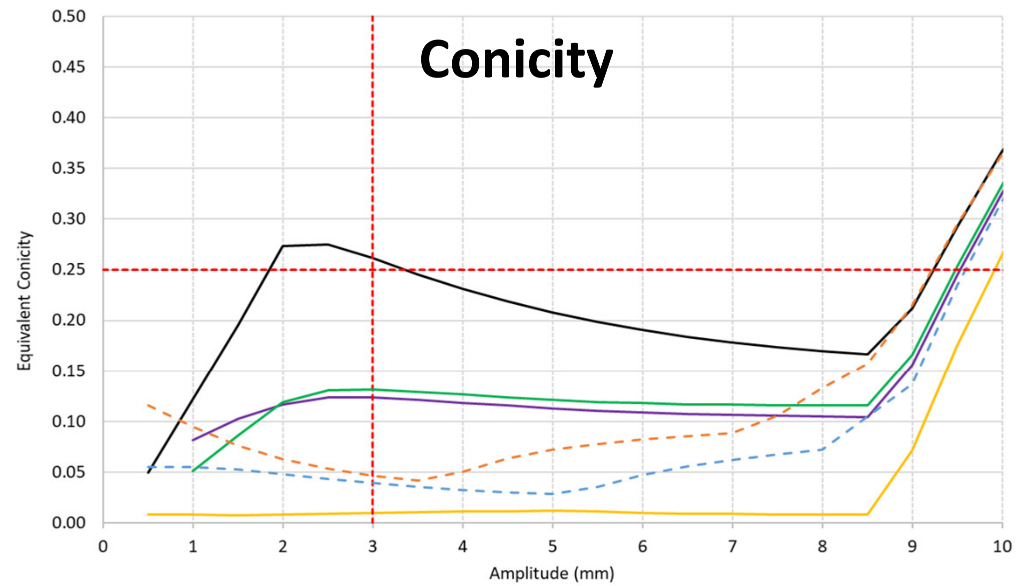
Considerations to altering wheel profile

- **It was important to consider key factors**
  - **Adjust wheel profile, or rail profile, or both**
  - **Metal removal to adjust rails or wheels to significantly different profile**
  - **Interfaces with other rollingstock or sections of track**
  - **Implementation plan timescales**

Outcome: Wheel profile modified significantly, minor modification to target ground rail profile

Outcomes





Original Wheel/Current Rail

Mod Wheel/Current Rail

Mod Wheel/Mod Rail

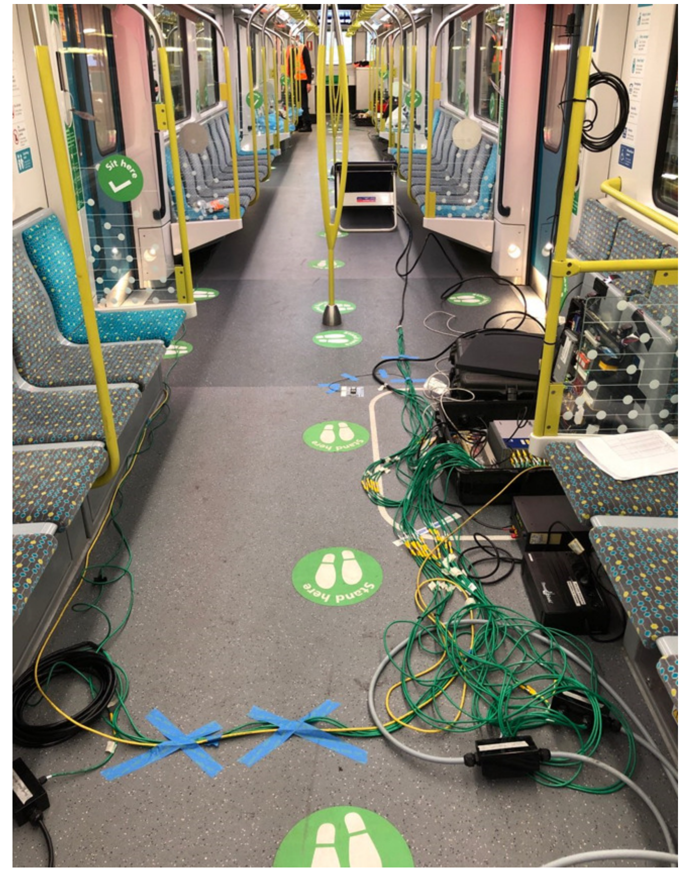
Original Wheel/Compatible Rail

Implementation Considerations

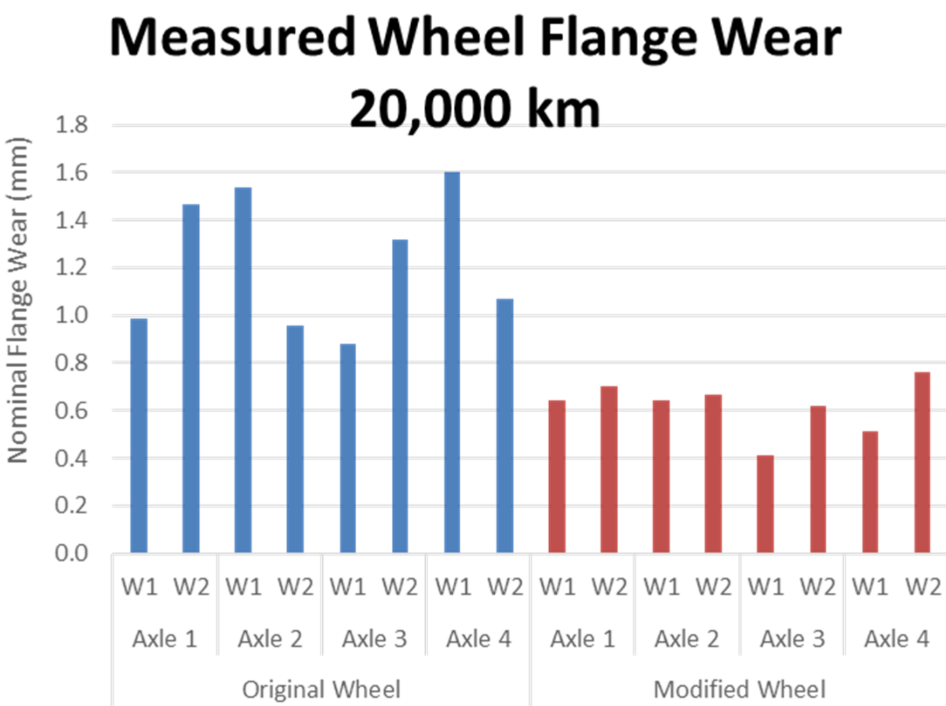
- Trial wheel profiles (initial and extended) – trial and control sets. Measurement is key, full profile not just Sd, Sh
- Implement wheel profile quickly across the fleet to reduce further damage and abnormal wear to track
- Trial rail profiles
  - Optional in this instance, as modified was very close to target, mostly case of implementing design. Generally monitor for at least one grinding cycle.
- Implement rail profiles – mix of grinding and milling

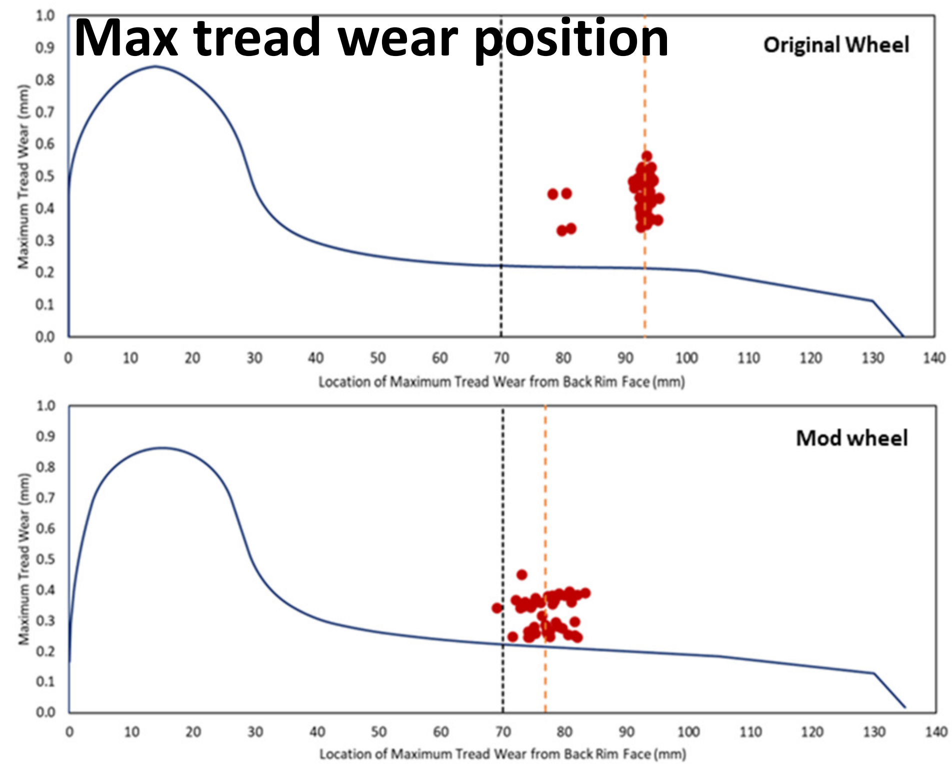
Testing

- Utilise Monash IRT's other capabilities to test vehicle stability on newly turned wheelsets
- The vehicle stability and ride safety within network specifications on modified wheel profile
- Additionally assessed against EN12299 (Ride Comfort) and AS 7509 (Hunting)



Monitoring and Validation





Summary

- Simulation provides a cost effective way of testing and improving the wheel/rail interface
- Allows for comprehensive testing for speed variations, profile changes and adhesion levels
- Case study of real world results confirming simulation outputs
- Benefits of having broader rail expertise behind the simulation – not just a number

References

Johnson, K.L. (2000), 'Plastic deformation in rolling contact', in Jacobson, B and Kalker, J (ed.), Rolling contact phenomena, Springer-Verlag Wien/New York, Udine, pp. 164-201.

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