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Optimisation of Wheelset Maintenance using Whole System Cost Modelling

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Overview

• Background
• Vision of VTISM
• Wheelset Maintenance Strategy
• Damage rates and WPDM
• Wheelset Costs
• Whole System Costs
• Summary
• Acknowledgements
Background

- Wheelset maintenance and renewal activities account for a large proportion of a fleet's whole-life costs.
- Influenced by a large number of factors:
  - Depot constraints
  - Wheel tread damage
  - Fleet availability
  - Vehicle design
- Optimisation of maintenance and renewal regimes will help to increase wheelset life and reduce costs.
• Tools currently exist for prediction of track damage, replacement and maintenance costs
  – Whole Life Rail Model (rail RCF & wear)
  – Track-Ex (NR decision support tool)
  – VTISM (links vehicle-track characteristics to track costs)
• Stage 2 development of VTISM enhanced the rolling stock modelling capabilities
  – Strategic planning of wheelset maintenance and renewal activities
  – Examine benefits and cost impact of a range of different scenarios
  – Optimise wheelset management strategies
• These enhancements go some way to determining the whole life costs for the complete system (vehicle-track)
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Vision of VTISM

Whole Life Rail Model

Track Inspection, Maintenance & Renewals

Wheelset Inspection, Maintenance & Renewals

Whole Life Rail Model

Wheel Profile Damage Model

Vehicle-Track Interaction & Forces

Vehicle Maintenance and Design Changes

Vehicles / Costs

Volumes / Costs

Vehicle

Interface

Track

Asset Data

Train Service Pattern

Maintenance & Renewal Policies

Track Maintenance Improvements

Route Data
Vision of VTISM

**Prediction of wheel/rail forces**

**Define asset data, initial conditions and limits**

- **Vehicle** → **Train Service Pattern** → **Vehicle-Track Interaction & Forces** → **Wheelset Inspection, Maintenance & Renewals** → **Wheel Profile Damage Model** → **Whole Life Rail Model** → **Track Inspection, Maintenance & Renewals** → **Whole Life Costs** → **Volumes / Costs**

- **Track** → **Maintenance & Renewal Policies** → **Track Maintenance Improvements** → **Vehicle Maintenance and Design Changes** → **Volumes / Costs** → **Asset Data**
Vision of VTISM

Prediction of rail wear and RCF damage

Define inspection, maintenance and renewal strategy
Evaluate asset condition over time and trigger track inspection, maintenance and renewals (T-SPA)

Determine whole life costs
Vision of VTISM

- Define inspection, maintenance and renewal strategy
- Evaluate asset condition over time and trigger wheel inspection, maintenance and renewals (W-SPA)

**Prediction of the rate of wheel wear and RCF damage**

**Determine whole life costs**
Wheelset Maintenance Strategy

**Inspection Strategy**
Applied if mileage since last inspection is greater than the relevant inspection interval

**Wheel Turning Strategy**
Triggered if condition reaches a pre-defined limit (i.e. flange thickness is less than the minimum permitted flange thickness)

**Wheelset Replacement Strategy**
Triggered if condition reaches a pre-defined limit (i.e. wheel diameter is less than the minimum diameter for running)
Damage Rates

- Rates of damage are included to describe how the attributes of the wheel deteriorate over time
  - Tread/flange wear
  - Change in conicity
  - RCF damage
  - Probability of flats

- Compared with pre-defined limits - trigger maintenance or renewal activity

- This information can be obtained from observation data
- Alternatively, the WPDM can be used to predict the damage rates
WPDM

- Wheel Profile Damage Model (WPDM) is a standalone tool for the prediction of deterioration rates of the wheel tread
- Uses VAMPIRE vehicle dynamics simulation software to predict wear and RCF damage
- WPDM methodology
  - Characterises a vehicle’s route diagram in terms of parameters which influence wheel damage
  - Predicts wheel-rail forces for the chosen route conditions using vehicle dynamics simulations
  - Post-process the calculated wheel-rail forces to predict the formation of wear (Archard model) and RCF (Ty-damage model) on the wheel
  - Plot and save the results for use within VTISM and WMM
Predicted Wheel Wear
Analysis Scenarios

• Mileage-based turning regime (Base Case)
  – Turning interval set to 140,000 miles to represent current practice
• Reduced mileage-based turning interval
  – Turning interval reduced to 100,000 miles to represent a ‘little and often’ turning regime
• Condition-based turning regime
  – Turning triggered by the condition of the wheelset only
• Lubrication strategy
  – Coefficient of friction at the flange contact was reduced to $\mu=0.1$
  – Inspection and maintenance of the lubrication system included
  – Includes modified wear and RCF damage rates for all wheelset types
• Modified primary yaw stiffness
  – Includes modified wear and RCF damage rates for all wheelset types
Wheelset Whole Life Costs

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Chart showing Wheelset Whole Life Costs:
- Mileage-based Turning (140k mile)
- Mileage-based Turning (100k mile)
- Condition-based Turning
- Primary Yaw Stiffness (140k mile)
- Lubrication (140k mile)

Bar charts for:
- Volume (Wheelsets Turned)
- Wheelset Turning Costs (£k)

Categories include:
- Turning for Parity
- Turning for Damage Depth
- Turning on Max Flats
- Turning on Mileage
Wheelset Whole Life Costs

- Reduced Turning Interval
  - Increase in mileage-based turning
  - Reduction in turning for damage
Wheelset Whole Life Costs

- **Reduced Turning Interval**
  - Increase in mileage-based turning
  - Reduction in turning for damage

- **Condition-based Turning**
  - Increase in turning for damage and parity
  - No mileage-based turning
Wheelset Whole Life Costs

- **Reduced Turning Interval**
  - Increase in mileage-based turning
  - Reduction in turning for damage
- **Condition-based Turning**
  - Increase in turning for damage and parity
  - No mileage-based turning
- **Primary Yaw Stiffness**
  - Increase rates of damage
  - Increase in turning for damage
• Reduced Turning Interval
  – Increase in mileage-based turning
  – Reduction in turning for damage
• Condition-based Turning
  – Increase in turning for damage and parity
  – No mileage-based turning
• Primary Yaw Stiffness
  – Increase rates of damage
  – Increase in turning for damage
• Lubrication
  – Reduction in damage rates
  – Increase in number of wheelsets achieving mileage-based turning
Optimised Wheel Turning Interval

- Total costs for varying wheel turning interval

![Bar chart showing total costs for varying wheel turning intervals.](chart.png)
Material Loss at Turning

- Low mileages – cut depth is governed by the amount of material loss required to restore the profile shape
- Higher mileages – similar cut depth to restore profile, but additional material removed due to RCF damage
• Increased intervals between wheel turning may result in a cost benefit to vehicle operators/maintainers
• But increases in wheel/rail conformality may result in increasing the probability of RCF damage on the track
• To reduce whole system costs (vehicle-track) it is therefore important to optimise both sides of the interface
Track-Wheelset Costs

Distribution of Flange Height

Distribution of Flange Thickness
Summary

- New tools have been developed which allow users to:
  - Evaluate wheelset whole life costs using fleet asset inventory data, deterioration rates and maintenance regimes
  - Determine annual inspection, maintenance and renewal costs
  - Optimise wheelset maintenance strategy
  - Carry out ‘what if’ analysis

- Capabilities of these new tools have been demonstrated by predicting the whole life costs for a typical DMU fleet
  - Cost implications of number of scenarios presented

- Tools can be used to determine the impact of system changes on both vehicle and track costs ≈ potential for reducing whole system costs
Acknowledgements

• The results and findings presented were developed from the RSSB managed rail industry research programme, funded by the Department of Transport

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