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Optimisation of Wheelset Maintenance using Whole System Cost Modelling

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Steve Mills – Rail Safety & Standards Board
Andy Rhodes, Daniel Ling – Serco
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)
Vision of VTISM

Vehicle Maintenance and Design Changes

- Train Service Pattern
- Maintenance & Renewal Policies

Vehicle-Track Interaction & Forces

- Whole Life Rail Model
- Track Inspection, Maintenance & Renewals

Wheelset Inspection, Maintenance & Renewals

Wheel Profile Damage Model

Volumes / Costs

Whole Life Costs

Volumes / Costs

Asset Data

Route Data

Track Maintenance Improvements
Vision of VTISM

**Prediction of wheel/rail forces**

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

**Whole Life Rail Model**

**Wheelset Inspection, Maintenance & Renewals**

**Whole Life Costs**

**Volumes / Costs**

**Vehicle Maintenance and Design Changes**

**Vehicles**

**Train Service Pattern**

**Vehicle-Track Interaction & Forces**

**Wheel Profile Damage Model**

**Track Inspection, Maintenance & Renewals**

**Volumes / Costs**

**Track Maintenance Improvements**

**Maintenance & Renewal Policies**

**Route Data**

**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
Wheel Profile Damage Model (WPDM) is a standalone tool for the prediction of deterioration rates of the wheel tread. It uses VAMPIRE vehicle dynamics simulation software to predict wear and RCF damage. The WPDM methodology involves characterising a vehicle’s route diagram in terms of parameters which influence wheel damage, predicting wheel-rail forces for the chosen route conditions using vehicle dynamics simulations, post-processing the calculated wheel-rail forces to predict the formation of wear (Archard model) and RCF (Ty-damage model) on the wheel, and plotting and saving 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

- Mileage-based Turning (140k mile)
- Mileage-based Turning (100k mile)
- Condition-based Turning
- Primary Yaw Stiffness (140k mile)
- Lubrication (140k mile)

**Volume (Wheelsets Turned)**

- Turning for Parity
- Turning for Damage Depth
- Turning on Max Flats
- Turning on Mileage

**Wheelset Turning Costs (£k)**

- 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
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

- **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
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

**Graph:**
- **Running Distance – 61,000 mile**
  - 0.6mm diameter loss due to wear
  - 2.5mm cut depth to restore profile

- **Running Distance – 178,000 mile**
  - 2.0mm diameter loss due to wear
  - 2.7mm cut depth to restore profile

**Optimum turning interval**
Institute of Railway Research

- 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.

**Whole System Costs**

<table>
<thead>
<tr>
<th>Turning Interval (miles)</th>
<th>Whole Life Costs (£)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min. Both</td>
<td>Wheelset</td>
</tr>
<tr>
<td>Min. Wheelset</td>
<td>Track</td>
</tr>
</tbody>
</table>

![Graph showing turning interval vs whole life costs for wheelset and track](image-url)
Track-Wheelset Costs

Distribution of Flange Height

Distribution of Flange Thickness

% Increase (+) or Decrease (-) in Cost Relative to Base Case

-45% -35% -25% -15% -5% 5% 15% 25% 35% 45%

100k mile 160k mile Condition-based Lubrication Primary Yaw Stiffness
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
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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