Introduction

The requirements for designing, manufacturing and maintaining wheelsets were developed over 30 years ago. In the intervening period greater emphasis has been placed on increasing the utilisation of vehicles and the intervals between maintenance. In addition to this, the advent of Technical Specifications for Interoperability and European Norms for the design and manufacture of wheelsets place greater demands on the understanding of these requirements and of the environment in which railway wheelsets operate.

Wheelsets are the single most critical component within a railway vehicle; and as such the industry demands high levels of confidence in their design and maintenance. In order to support industry's ever increasing expectations, the fundamental understanding of the current wheelset environment needed to be better understood. This project was initiated with the intention of improving knowledge and understanding of the wheelset environment.

The wheelsets used on European trains are not significantly different to those on GB trains; however, understanding the differences and how they could affect wheelsets introduced on new trains could provide significant. As part of the process to understand the European philosophy, RSSB sought engagement in a European-funded project 'WIDEM' to gain an understanding of the considerations for wheelset design, and to influence the direction of future requirements. This was done on behalf of the Vehicle/Track System Interface Committee (V/T SIC) and the Wheelset Management Group (WMG).

Aims

This project set out to establish how the operating environment influences the design and operation of wheelsets being used on today's railway. To understand how this was to be achieved some key questions were asked:
Using an appropriate sample of axles, what are the real stresses experienced in service on Network Rail infrastructure?

What track features give rise to axle strains that have a significant influence on fatigue life?

Which wheel features impart the most significant loads (vertical or lateral) to the track, such as out-of-roundness, flats, wobble?

Are the existing dynamic load factors, as defined in current axle design codes, appropriate? If not, should this be taken forward as a separate project?

Given this information:

- How might we revise the maintenance and inspection of existing wheelsets? (Includes consideration of the effect of the stress raisers such as stress corrosion, surface treatments, and other protection methods, as currently experienced in GB’s rail industry.)
- How might we revise axle design rules and associated maintenance and inspection?
- What can be learnt from continental experience in this area and what would be the effect of trains designed to European standards running on GB track?
- What impact can this work have on Euronorms, and how best can we influence further developments?

This project collected axle strain data and other information describing the wheelset environment over a long period. This allowed changes in vehicles, track conditions, weather, and seasonal effects to be assessed in a rigorous and scientific manner. Analysis of the data, together with vehicle simulation, has led to a proposed methodology for synthesising axle stress histograms.

**Findings**

The final report describes the principles of the proposed methodology and how the constituent elements of the methodology were developed. The sensitivity studies identified the parameters essential in the process of synthesising axle stress histograms as:

- Route
- Vehicle, bogie, and suspension layout
- Static axle load
- Passenger load spectrum
- Braking (some braking configurations can be ignored)
- High-frequency behaviour
All the parameters considered have been described within the final report, including those parameters that may be included and those that are not explicitly required in the synthesis methodology.

The methodology developed was validated using data gathered from a Class 319. The methodology was then applied to the Class 319 trailer axle to assess different maintenance and inspection strategies that could be applied to it. This study identified the potential to reduce the minimum axle diameter to permit axle body reclamation, or to increase axle inspection periodicity (potentially eliminating in-service axle testing).

Method

The Optimising Wheelset Design and Maintenance research has been delivered as a number of separate steps. These included definition of service routes; measurement and analysis of wheel/rail forces; and appropriate adjustments to the VAMPIRE vehicle models to produce the final axle stress spectrum.

The final report describes the principles of the proposed methodology and how the constituent elements of the methodology were developed. The methodology was validated by replicating the axle stress histograms for a range of vehicles. This validation was based on a period of two months' running of the Class 319.

A number of additional investigations and analyses were also carried out, which included:

- Determination of the locations on the test route where particularly large strains and accelerations were observed.
- Consideration of the frequency content of the measured bending and torsional strains and accelerations; and how the frequencies relate to the possible sources of strains and accelerations.
- Analysis of the Class 319 unit, running on depot tracks previously considered to be the source of damaging cycles.

The recorded data was assessed in order to address the aims of the project, which are to:

- Characterise the influence of track and vehicle parameters on axle strains.
- Propose a methodology for synthesising axle stress histograms.
Figure 1: Proposed methodology
A preliminary sensitivity study was undertaken to establish how track-based and vehicle-based parameters influence axle strains. This preliminary study identified those parameters that will need to be included in any predictive model and those that should be included.

The sensitivity study was based on failure probabilities. This process defined the key parameters to be included in the methodology.

A methodology was formulated for the synthesis of axle stress histograms. The synthesised stress histograms can be used in probabilistic fracture mechanics to calculate the axle failure probability in service, as a function of non-destructive testing periodicity.

**Next Steps**

Although there is a substantial body of information from axle strain measurements that have been recorded over recent years there are still some vehicle configurations not supported by reliable strain gauge data. In order to support industry in providing mechanisms for understanding the wheelset environment, further data should be obtained for the following vehicles, which the WMG will coordinate as part of the WMG wheelset research programme.

- Freight vehicles, the choice of vehicle, bogie, and suspension type would need to be defined in conjunction with industry stakeholders.
- Locomotives, particularly long-wheelbase, 6-axle vehicles, although there is limited information available for 4-axle vehicles.
- The powered axles of multiple unit vehicles, concentrating on modern drive systems, although axle-hung traction motor systems would be revisited.

Information produced as part of this research project is already being used in further research projects such as T728 Impact of corrosion upon the high cycle fatigue properties of GB axle steel. T728 will increase industry's knowledge of the effects of damage and corrosion on the fatigue life of axles; which will assist in optimising wheelset whole life costs without adversely affecting safety.
Industry will be able to use the data collected as part of this project to optimise design and maintenance of wheelsets to give the lowest whole life cost. This could deliver savings and reduce risk from current wheelsets by reducing the amount of intervention for axle testing in maintenance depots.

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