Whole Life Rail Model Application and Development for RSSB – Continued Development of an RCF Damage Parameter (T115)

Background
The Rail Safety and Standards Board (RSSB) has been developing the Whole Life Rail Model (WLRM) by contracting with AEAT Rail, the University of Sheffield and Interfleet Technology, to improve the industry’s understanding of Rolling Contact Fatigue (RCF) initiation and growth. Improving the fundamental understanding of RCF and capturing it in the development of the WLRM will enable the industry to manage RCF more effectively.

Aims
The objective has been to develop a parameter, which is able to predict the crack locations on a site at risk from developing RCF and determine the timescale over which initiation would take place. The results of such modelling would further the understanding of the manner in which rails respond to the fatigue forces imposed on them by passing vehicles and the mechanisms by which RCF cracks develop.

Method
Initial modelling performed on two sites allowed assessment of various crack initiation parameters. This work describes modelling of four further sites on the route between London and Southend, and the detailed development of an RCF crack initiation model.

For each site, vehicle dynamics simulations were performed for each of the vehicle types that had operated over the sites, to determine the transient forces developed at the wheel/rail interface during curving, where more predictable quasi-static forces exist.

These forces were then used as inputs to the RCF crack initiation model. This model used an RCF damage parameter to describe the material response to these forces, allowing the level of fatigue damage for each passing vehicle to be quantified. For each site, the RCF predictions for the vehicle types and appropriate range of worn wheel profiles were constructed and assembled in the proportions in which the vehicles were present at the site.

This provided a picture of the full fatigue history of the site and allowed the RCF crack initiation life of different parts of each site to be predicted. These predictions were then compared with the locations and surface lengths of the RCF cracks, which were measured during the site surveys, to assess the quality of the predictions from the RCF crack initiation model.

The best predictions of the occurrence of RCF cracks were obtained using a damage parameter derived from the energy expended in the contact patch by each passing wheel, and included the effects of wear/fatigue interaction.

Findings
Of the four sites modelled in this stage of the project, the initiation model was able to provide good predictions of the locations at which cracks were observed for three of them. Figure 1 shows a comparison between predicted locations (blue areas) and measured locations (orange areas) for one site.

![Figure 1: Comparison of predicted and measured locations](image-url)
For the fourth site, simulations were only available for a limited number of vehicles so it was not possible to construct a full RCF history of the site.

The model has been shown to provide good predictions for RCF cracks generated by a number of mechanisms. These included quasi-static curving forces, where the influence of track geometry is minimal; and situations where the forces responsible for generating cracks result from the influence of the track alignment on vehicle behaviour. In summary, track geometry misalignments were found to act to prevent RCF cracking on curves, but promote it on transitions. The importance of good wheel and rail profile maintenance was shown, where simulations predicted that a significant reduction in the volume of RCF crack generation could be achieved through improvements in wheel and rail profile maintenance standards. Figure 2 shows predicted running bands for new P8 profile (upper) and a worn one after 116 000 miles (lower). Traction forces were also shown to be of sufficient magnitude to be capable of initiating RCF cracks.

**Further information**

Other RSSB reports related to RCF research include:

**University of Sheffield and AEATR, WL RM, Interim Report.** This report was completed in September 2002 by the University of Sheffield and is a progress report on the development of crack initiation modelling, modelling the growth of longer fatigue cracks (phase II), wear modelling and material property analysis.

**Whole Life Rail Model - Initial Assessment of the Influence of Wheel Profile Changes on RCF Formation.** This report was completed in February 2003 by AEATR and the University of Sheffield and was an initial investigation into wheel profiles. It concentrated on a small number of profile designs and vehicle types in terms of RCF propensity. The project helped to influence the direction of the RSSB (at the time, Railway Safety) RCF research.

**Whole Life Rail Model - Six Month Report.** This report was completed in May 2003 by AEATR and was a summary of progress to date on RSSB RCF Research. The research included the development of the:

- WL RM wear, initiation and crack growth models
- Laboratory testing
- Investigations into the role of irregularities on RCF formation
- The application of the WL RM to investigate whether new wheel profiles can help to reduce the incidence of RCF

**Whole Life Rail Model Application and Development - Dynamic Modelling of Rolling Contact Fatigue.** This report was completed in October 2003 by AEATR and describes research undertaken into the effects of vehicle dynamic behaviour on the formation of RCF. With assistance from work led by the Wheel Rail Interface Systems Authority, the validation work was performed at Acton and Ruscombe
Junction. Large variations in contact conditions were found at both sites, which were related to the presence of RCF cracking. Mitigation actions for both sites were proposed.

Whole Life Rail Model Application and Development - Development of an RCF Damage Parameter. This report was completed in October 2003 by AEATR, and describes the research undertaken in developing a damage parameter capable of describing damage associated with RCF. The research was based around the Acton and Ruscombe Junction sites and used dynamic simulations of the vehicles that operated on the site.

Whole Life Rail Model Rolling Contact Fatigue Laboratory Testing. This report documents work undertaken by AEATR and describes laboratory testing to simulate wheel/rail conditions that initiate rail RCF. Four tests were performed using two rail materials, standard rail and MHT (Mill Heat Treated). Each material was tested in the dry condition and also with lubrication (run for intermittent periods with water being applied to the wheel/rail interface). Subsequent microscopic examination of the railhead and sections through the rail contact area assessed damage and the possibility of RCF initiation.

Acknowledgements
RSSB would like to thank the Vehicle/Track System Interface Committee and its Permanent Project Group for their assistance in delivering this work.

Contact
Head of Engineering Research
R&D Programme
Rail Safety and Standards Board
research@rssb.co.uk