ProRail predicts RCF hotspots

Analysis of inspection data has enabled ProRail to identify key factors contributing to the development of rolling contact fatigue, and the development of a prediction methodology to help manage the problem more cost-effectively

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ROLLING CONTACT FATIGUE is a treacherous phenomenon. It is one of the main reasons for premature replacement of rails, because RCF can usually only be detected at the point where maintenance no longer has any effect and replacement is the only option. In 1999 the European Rail Research Institute estimated the total cost of RCF to European railways at €300m a year. But over the last three years the scale of the problem and the cost have increased significantly.

A Dutch study in the mid-1990s found that the probability that head checks would lead to a vertical rail break was much greater than had been assumed[1]. By the end of the 1990s railways across Europe were reporting a significant increase in the extent of RCF, and the implications were graphically demonstrated by the high-speed derailment at Hatfield in October 2000 which was the result of a multiple rail break.

Following Hatfield, Dutch infrastructure manager ProRail formed a national RCF project team in 2001, in conjunction with AEA Technology Rail and NedTrain Consulting (RG 7.03 p433). But it seems clear that the current regime of visual inspection and rail replacement is not the most cost-effective way to monitor and control RCF. An automated inspection system is now under development and this will help to identify head checks and squats on a regular basis.

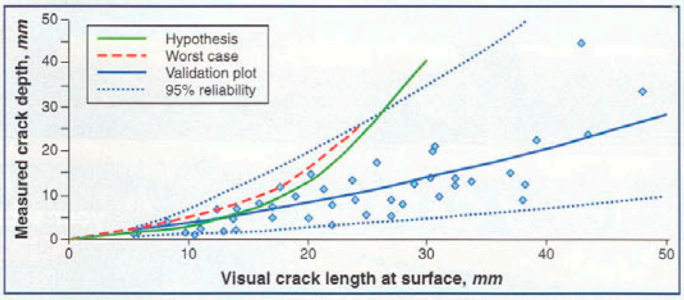

Fig 1. Validation of the visual classification method for identification of head checks during track inspection

ProRail has analysed its field data on RCF damage to increase its understanding of the sensitivity of different parts of the network to the development of head checks. This will enable maintenance and control measures to be concentrated on the most critical areas, extending rail life and reducing the overall costs. These preventative measures are now being translated into ProRail's policy, regulations and operational processes.

Scale of the problem

The first step for the project team was to initiate a network-wide visual inspection, using standardised damage classifications (RG 7.03 p435) to ensure uniform reporting by all contractors. AEA Technology Rail provides a helpdesk giving assistance during inspection, has developed the RCF database and undertakes data analysis for the project.

For inspection purposes, the network was divided into 50 m sections, which are classified by the maximum length of crack found in that section. Field data is collected by the inspectors using palmtop PCs and then uploaded to the main database.

Around 80 inspectors from the three main contractors, Strukton, BAM and Volker Stevin, undertook an initial two-month survey of 4 200 track-km where line speeds were 100 km/h or more. This found head check damage totalling 293 track-km, and all sites where the damage was classified Heavy or Severe were subsequently tested ultrasonically. The ultrasonic test results, actions taken, and timescales are also included in the database.

The visual classification model, which relates surface crack length to crack depth, was validated through accurate measurement of 50 damaged rail sections removed from the track. Fig 1 shows that the model is slightly conservative for longer cracks, but is an accurate, safe and reliable tool for initial classification of head checks. For cracks up to 10 mm long, the actual depth was sometimes greater than predicted, but this does not create an unsafe situation. For longer cracks the actual depth was always less than the predicted value.

Analysing the data

The RCF damage database compiled in June 2001 was combined with track data such as curve radius, cant, sleeper type, traffic type and line speed. This allowed the occurrence of head checks to be analysed for different parameters. As expected, damage was mainly observed in curves of between 1 000 and 3 000 m radius and in switches (Fig 2).

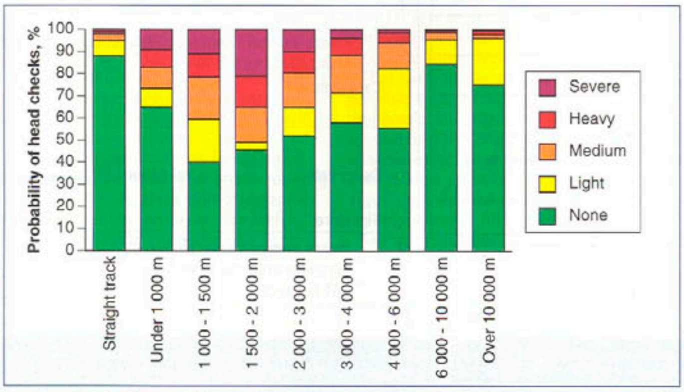

Fig 2. Probability of head check damage when compared to curve radius

Recent investigations indicate that the likelihood of cracking depends on a number of parameters[2]. The ProRail RCF database is still being developed, and does not yet include all of these para-

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meters in a form that makes it possible to assess their effect quantitatively. However, assessments can be done for curve radius, cant deficiency, sleeper type, rail section, and traffic type.

This preliminary analysis appeared to show various trends, but it was not clear whether the observed behaviour was actually caused by the suspected parameter. For example, the degree of RCF appeared to be consistently lower for NP46 rail compared to UIC54. This could be simply because UIC54 rail is generally laid in curves most prone to RCF, or because UIC54 routes carry a more damaging mix of traffic.

Sampling analysis was used to determine whether the apparent relationships were valid. The basic principle is to calculate the probability of RCF as a function of one parameter, where the distributions of all other relevant parameters are constrained to be similar.

For example, when considering the apparent relationship between RCF and sleeper types – timber, concrete monoblock and twin-block – the RCF probability is calculated for a number of subsets of the data with similar distributions of curve radius, rail section and so on. The overall probability of RCF for each sleeper type is then given by a weighted average of these subsets. This probability can be interpreted as relative or absolute depending on the proportion of the complete RCF data included in the sample.

A number of sampling analyses have been carried out. One confirmed the suspected effect of rail profile, with a 2·8% probability of RCF for the 27·8% of the network laid using NP46 rail compared to 8·8% for the 72·2% laid in UIC54. The actual reason is thought to be the different rail inclinations of NP46 (1:20) and UIC54 (1:40), which results in different contact conditions.

Table 1 ranks sleeper types used in the Netherlands in increasing order of RCF probability, which is also generally in order of increasing track stiffness. One possible explanation is that lateral stiffness determines the degree to which a rail will roll under a wheel, and thus the precise contact conditions.

Switch & crossing work sees significantly higher probabilities of RCF than plain track. This could be due to differences in rail inclination, rail stiffness, or to the geometric irregularities associated with S&C.

Sampling analysis on traffic patterns clearly shows that the ICM EMUs were associated with high levels of RCF. Damage levels for the double-deck IRM units were only slightly higher than for other vehicles, but there are relatively few routes where IRMs are the dominant type of rolling stock, and their proportion is never greater than 60%. Thus any effect of IRMs on RCF damage will not show up so clearly.

Table 1. Probability of RCF compared to sleeper type

Sleeper type	% of route	Probability of RCF %
Timber	51·2	5·1
Twin-block	26·5	7·2
Concrete	9·8	14·2
Adjustable	1·2	16·1
Slab track	0·6	23·0
Switch & crossing work	11·0	8·9

Source: Susceptibility analysis

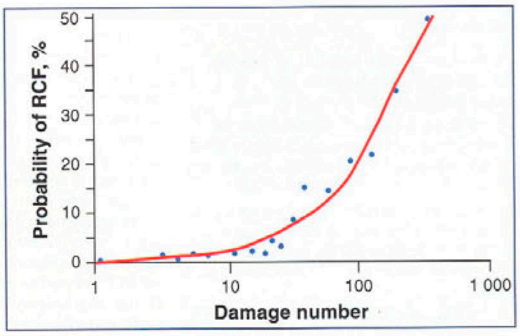

Fig 3. The damage number methodology provides a good correlation with the probability of RCF development

Using damage numbers

Having found that the probability of RCF development is a function of curve radius, sleeper type, rail section, and traffic pattern, these parameters can be brought together to develop a prediction methodology. This will enable the sites most at risk of RCF to be identified, so that remedial measures can be prioritised.

Damage numbers are assigned according to curve radius (Dr), sleeper type (Ds), rail profile (Dp) and traffic pattern (Dt) based on the results of the sampling analyses. Each section for which all the data is available can then be assigned an overall damage number (D) defined by:

$$D = Dr \times Ds \times Dp \times Dt$$

The predicted total damage is then correlated against the observed probability. Fig 3 shows that there is indeed a strong correlation.

The damage number approach is being used as the basis for an RCF prediction methodology, on which development started at the beginning of 2003. Based on validated track inspection data, this model is intended to forecast RCF-related costs over a five-year period, making budget estimates more accurate. In time, the predictions will almost certainly be improved by including additional factors, particularly some measure of geometric track quality, which is believed to have a significant bearing on RCF development.

RCF control strategies

We believe that traditional rail steels have probably reached their technical limit when dealing with the extremely high stresses at the wheel/rail contact patch. As crack initiation is very difficult to prevent, future development will be focused more on controlling crack propagation.

ProRail's RCF control strategy is based on three main deliverables (RG 7.03 p433): introduction of head check resistant rails, reducing contact stresses through improved rail and wheel profiles, and a cyclical preventative grinding programme.

Two types of RCF-resistant rail are being considered. A test section of Micro-alloyed Head Hardened rail from Corus France was laid on a 2 500 m radius curve, with 60 mm of cant, used predominantly by commuter trains with a maximum axleload of 22·5 tonnes at a line speed of 140 km/h. This section has now been in service for 23 months, during which it has carried 30 million gross tonnes. So far all the test sites have only shown micro-cracking, compared to medium-class head check damage on the matching control sample of standard 260Mn rail (Fig 4).

The MHH rail has its microstructure crack-retarding properties optimised through off-line heat treatement to refine the lamellar spacing. This also produces an extremely fine structure for pre-austenite grain size. MHH heat treatment results in full compressive residual stress distribution in the head of the rail, further contributing to controlling crack growth rates.

Following these test results, ProRail has adopted new rail grade selection procedures; at re-railed curves considered

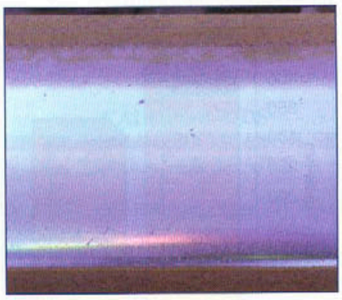

Fig 4. Comparison of rail damage to MHH test section (above) and standard 260Mn rails (below) after the passage of 30 MGT

to be sensitive to head checks (with a radius between 750 and 3 000 m, cant deficiency greater than 50 mm and an axleload of more than 18 tonnes), MHH rail will be installed for the high rail.

A field test has also been authorised with the Infrastar two-material rail (RG 9.03 p587). Prototype rails have already been delivered for analysis, and a test section is to be laid early this year. The chosen section of line has a history of RCF damage, a 1 000 m radius curve with 80 mm of cant, a line speed of 120 km/h and a maximum axleload of 22·5 tonnes, and carries 12 MGT/year. As well as 50 m of two-section rail, a 240 m length of 370LHT grade rail from Voestalpine is also to be installed on this curve.

Since mid-2002, ProRail has been grinding sensitive sections of track to a new anti-head check rail profile, based on research by the ERRI D173 committee, and field testing has shown very positive results. Newly-ordered MHH rail is now being supplied with this profile, symmetrically rolled during production. Grinding work is continuing to apply the new profile to all existing curves identified as sensitive to head check propagation.

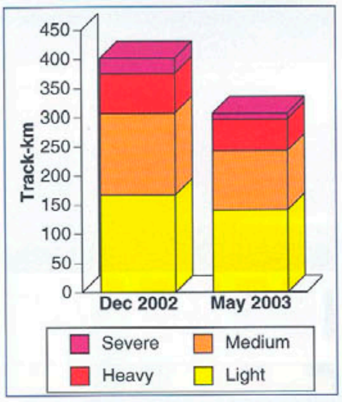

Fig 5. Development of head check damage on the Dutch network for lines with speeds of 40 km/h or more, based on inspections in December 2002 and May 2003

Corrective grinding in the Netherlands has generally been aimed at dealing with noise (roughness/corrugation) and side wear. In conjunction with Network Rail and NRC, ProRail is currently developing an RCF preventive grinding strategy to restore the balance between wear and crack growth. Class 1 curves between 750 and 3 000 m are to be ground after 15 MGT, Class 2 curves between 3 000 and 9 000 m every 30 MGT, and Class 3 curves greater than 9 000 m radius at 45 MGT intervals. Class 1 and 2 grinding intervals will probably be lengthened where resistant rails and revised profiles have been introduced – ideally to the same interval required for plain line.

By preventing cracks from growing too deep into the railhead, the RCF grinding strategy is expected to halve the rate of rail replacement. As the grinding cost is only 10% of the cost of re-railing, a high return on investment is expected. This excludes the related cost of avoiding temporary speed restrictions, which can also be very high.

Future developments

Visual inspection of the complete network is now being repeated every six months, providing a much greater depth of information for the RCF database. The inspection has been extended from head checks to cover squat damage as well. The RCF data is now linked to that from ultrasonic inspection of crack depths and data on rail replacement, enabling the project team to manage the complete RCF detection and follow-up process.

Using the database and track inspection results we can now produce a monthly update on the development of RCF damage (Fig 5). These graphs confirm that the head check problem is being controlled, and the size and severity of head check damage on the ProRail network is gradually decreasing. The number of temporary speed restrictions and special measures required to combat RCF has decreased considerably since 2001, although the cost remains high.

To speed up the inspection process, a train-mounted system to detect head checks based on crack length measurement is being developed, which could operate automatically in future. Field trials and validation of the equipment was due to be completed by the end of 2003. A non-destructive method for accurate measurement of crack depth is also being developed, and further work is underway to optimise wheel and rail profiles. ■

ProRail prédit les points chauds du phénomène de fatigue au point de contact du roulement

L'inspection visuelle globale du réseau ferré hollandais et l'analyse avancée des données ont rendu ProRail et ses partenaires de projet capables d'identifier les facteurs clés participant au développement du phénomène de fatigue au point de contact du roulement. L'affectation de numéros de dommage à ces variables a permis le développement d'une méthodologie de prédiction et une prévision des coûts du phénomène de fatigue pour les cinq années à venir. Des essais sur le terrain commencent avec un équipement monté sur un train afin de détecter le phénomène automatiquement

ProRail sagt Rollkontaktermüdung-Hotspots voraus

Eine umfangreiche visuelle Inspektion des niederländischen Bahnnetzes und weitgehende Datenanalysen erlauben es ProRail und deren Projektpartnern die Schlüsselgrössen zur Bildung von Rollkontaktermüdung zu identifizieren. Die Zuordnung von Schadensnummer zu diesen Variablen ermöglichte die Entwicklung einer Vorhersage-Methode sowie eine Voraussage über die Kosten der Rollkontaktermüdung über die nächsten fünf Jahre. Feldversuche beginnen demnächst mit fahrzeuggebundenen Einrichtungen zur automatischen Erkennung dieses Phänomens

ProRail predice los casos de la fatiga del contacto de rodadura

Una inspección visual global de la red ferroviaria holandesa y un análisis avanzado de los datos ha permitido a ProRail y a sus socios de proyecto identificar los factores clave que contribuyen a la fatiga del contacto de rodadura. Asignar números de daño a estas variables ha permitido el desarrollo de una metodología de predicción, y una previsión de los costes de la fatiga del contacto de rodadura en los próximos cincos años. Comienzan las pruebas en vía de un sistema instalado a bordo de trenes para detectar el fenómeno automáticamente

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