Successful examples of co-operation in wheel rail interface management in the Netherlands

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1. Introduction: management of traffic, trains and tracks in the Netherlands

Every day, some 1.2 million passengers and 100,000 tons of freight are transported on nearly 7,000 km of railway line. There has been a steady increase in the number of regional and freight train operating companies, serving these passengers (to 36 in 2009). New train operating companies are able to enter the railway network after rolling stock acceptance, which is managed by the Transport & Water Management Inspectorate, and the allocation of slots according to non-discriminatory procedures by ProRail.

The situation on the Dutch rail network is thus characterised by separated infrastructure management and profit-driven operators, some being paid by regional governments through tenders. Nederlandse Spoorwegen (NS) is by far the largest operator (some 80% of passenger train km), operating the main network services under a concession until 2015. The infrastructure manager ProRail is responsible for constructing, managing and operating the infrastructure. Infrastructure use is charged on a variable cost basis, which includes the tonnage borne by the infrastructure. The tonnage borne is constantly monitored by the “Quo Vadis” weigh-in-motion (WIM) systems that are located at strategic points on the network and capture practically all traffic movements in real time. A critical management task is keeping the assets in a predefined level of quality (e.g. maximum allowed amounts of non-availability are specified). ProRail has arranged its maintenance management process therefore according to the model shown in Fig. 1.

![Fig. 1: Performance of track management in four coherent layers (RAMSHE: Reliability, Availability, Maintainability, Safety, Health, Environment)](image)

Performance data is collected, summarised and monitored at several levels. For instance, overall track geometry quality is indicated by a single KPI (key performance indicator) figure for sections of track, but also at detailed levels so that it can be linked to specific maintenance activities. A considerable part of the maintenance process has been outsourced to contractors, who can enter the maintenance market through public tendering procedures. The contracts tendered cover a maintenance period of 5 years and specified geographical areas. When major renewals are required, these are set up as separate projects for tender. The level of output achieved during the contract period is critical for the success of the contractor and the sustainability of the ‘cooperation’ between ProRail and the particular contractor. The contract can be terminated in case of poor performance. During the contract period, quality checks are made and performance data is being shared between ProRail and the contractor. For specific safety-critical activities, ProRail specifies in more detail its requirements and work methods. For example, inspection intervals and data collection are issues that are not decided by the contractor, but are determined by ProRail’s Asset Management Department.

This paper discusses the particular approach developed to combat the causes for rolling contact fatigue (RCF) development on the Dutch network, which emerged over the last 10 years. ProRail developed, in
close collaboration with Netherlands Railways (NS) and NedTrain, strategies to reduce the occurrence of the now (internationally) well-known phenomena of Head Checks and squats. This article briefly looks back at the practical approach adopted by ProRail towards managing RCF, first from an infrastructure-only perspective and subsequently through a full wheel-rail system perspective. A number of case studies that successfully reduced the impact of RCF are discussed, after which some conclusions and recommendations are drawn.

3. RCF and infrastructure-related measures for improved wheel rail contact management

Tracks, turnouts and level crossings belong obviously to the critical assets of ProRail, as is the case for each Infrastructure Manager. Failing track, such as rail breakages and defect insulation joints, and turnouts make train operation impossible or require the implementation of serious speed restrictions (e.g. 40 km/h). The track assets of ProRail have a replacement value of about EUR 8 billion (out of an estimated EUR 30 billion for the total system) and, each year, their upkeep accounts for a significant share of the total maintenance costs. In the years after 2000, the need for maintenance and renewal was increasing not only because of the normal replacement requirements but also due to an increasing level of RCF. It could be argued that, after the restructuring of the former NS holding, in 1997, wheel/rail interface management was not given proper attention. At the time, NS was preparing to become a stock market company, which led to short-term optimisation of their internal processes. ProRail did not exist at the time, but instead there were three separate ‘task organisations’ on the infrastructure side that worked under the auspices of the Ministry of Transport & Public Works, which were later integrated into ProRail (now 5 years ago). The execution of maintenance was already outsourced to contractors, but the way in which the contracts were to be organised and managed still needed to be developed.

Fig. 2: Head Checks and Squats – severe examples

Since 2001, ProRail has been actively investigating the causes of RCF and has developed strategies to reduce its occurrence [1]. Fig 2. shows typical Head Checks occurring in the Netherlands - initially, RCF occurred in the form of so-called Head Checks, which many European railways have become familiar with and, later on, in the form of Squats. It was clear that the costs were increasing rapidly (already approx. 50 million euros in 2005) and that unchanged policy could not be sustained. It also became clear that the causes for the sudden increase in the occurrence of RCF are multiple (such as the introduction of trains with a higher seating capacity, an 8-10 times increase in bogie yaw stiffness (e.g. double-deck intercity trains)). In Fig. 3, changes with respect to both wheel and rail that have contributed to the increase in RCF defects are shown.

Fig. 3: The typical changes that wheel/rail interface has experienced in The Netherlands

After the RCF problem had been sufficiently recognised, in which also the Hatfield accident in the UK played a role, ProRail developed strategies and procedures for dealing with RCF. The initial strategy was to improve the detection of RCF by adopting better inspection techniques (e.g. improvement of ultrasonic rail
inspection and adoption of new techniques, the latest development being eddy-current technology) and to renew sections of rail needing replacement, in order to get the track into a certain basic condition. A rail inspection train, using ultrasonic and eddy-current technology, initially identifies RCF defects. Elements of the track those are not measurable by the rail inspection train (such as points, etc.) need to be measured by manual devices. In The Netherlands, until 2008, RCF inspection campaigns (by ultrasonic rail inspection train and, in parallel, visual inspections) were conducted twice a year. Since 2009, inspections are conducted at least twice a year, up to four times a year, depending on track classification according to UIC Leaflet 714 [2]; Head Checks are categorised into four defect severity classes and squats into three.

It was found that rails are subjected to a ‘stress regime’ (i.e. high friction and loads resulting from the passage of trains), which, if no countermeasures are undertaken, leads to RCF and, thus, a shorter service life of the rail [3]. Once damage occurs, the deterioration process of the rail accelerates. This process can be slowed down on 54E1 rails by grinding – in fact introducing artificial wear so that Head Checks are eliminated in their initial stages and have no opportunity to develop into deep defects.

Preventative rail grinding was implemented in 2004 (pilot phase) and 2005 (national roll-out), with different grinding intervals for different loads and curve radii – directly adopted from Canadian heavy-haul practice [4]. It took a number of years to get the entire railway network into a certain basic condition, after which more limited grinding intervals and depths could be adopted, which was the case in 2008. The preventative rail grinding strategy adopted has led to a 75% reduction in the occurrence of the most severe category of Head Checks on straight track: i.e. from 25 km affected with severe Head Checks in 2002 to 5 km in 2007 – see Fig. 4. The business case for the preventative rail grinding strategy was strong from the start. It was estimated that, considering only direct RCF maintenance, each EUR 1 invested in preventative rail grinding would bring more than EUR 3 in return. Preventative rail grinding also leads to a reduction in the occurrence of corrugations, as better wheel/rail contact properties and reduced dynamic forces are achieved which, in turn, leads to an increase in the service life of the rail.

Another result of the research programme into RCF is the use of a so-called “Anti Head Check” rail 54E5 profile in curves with a radius $R < 3,000$ m since 2006, and also started in turnouts (Fig. 5). This 54E5 profile has been designed and analysed by a PhD research [5]. Further, different rail steel qualities are applied, depending on location. Currently, studies into new types of rail steel material, e.g. Bainite, and scientific research into the initiation of squats are underway (the occurrence of squats is a matter of major concern). Although increased knowledge has been obtained in the last few years with respect to their initiation and growth development, in order to get a grip on the prevention of squats, more research will be needed. First results and models to predict squat initiation and maintenance regulations will be expected in 2012).
4. Taking an integrated approach in wheels and rails management

In summary ProRail achieved a lot through the infrastructure-sided measures such as improved RCF detection, implementation of preventative rail grinding, an anti Head Check rail profile, and better coordinated planning of rail maintenance. However, it was also realised that it would only help to a certain extent and can never “combat” the Head Check problem at source, by e.g. avoiding the exertion of unnecessary load and friction onto the track. In addition, in 2007 and 2008 it was recognised that wheel and rail are subjected to similar RCF problems, as there is a relationship between wheel and rail in the obvious sense: the wheel being in constant contact with the rail. This means that changes to the wheel profile, the material used and maintenance would also have an influence on the rail. Optimising wheel maintenance, as well as adopting a more “track-friendly” design, contributes to an increase in the service life of both wheel and rail (see also [6], for more details). Based on this train of thought, in the Netherlands, the wheel/rail interface has since then not only been optimised from the side of the rail but also from that of the wheel.

The following strategies have been implemented to combat RCF from the side of the wheel:
- Optimisation of the wheel profile;
- Optimisation of wheel reprofiling intervals.

An ongoing development is implementing and fine tuning wheel flange lubrication as a means to manage track wear as well as other parameters such as noise levels.

5.1 Optimisation of the wheel profile

Until 2005, the UIC-ORE S1002 wheel profile was used for all passenger trains in The Netherlands, which was developed in the 1970s. Since that time, railways have seen significant changes. Heavier axle loads and increased bogie yaw stiffness have been introduced, which has resulted in new problems, among which the occurrence of RCF. Optimising the wheel and/or rail profile is one way to reduce the occurrence of RCF. A logical approach would be to optimise both wheel and rail profiles. However, as this is such a complex problem, in The Netherlands, first the rail profile was optimised separately, based on the principle that the gauge corner of the rail should be relieved, which resulted in the “Anti Head Check” 54E5 rail profile mentioned earlier. Subsequently, based on this “Anti Head Check” rail profile, the wheel profile was optimised, the goal being to reduce spin and slip forces and increase the wheel/rail contact area, see reference [5]. This resulted in the development of the so-called “HIT” wheel profile, which NS has adopted for intercity coaches. Wheels of suburban trains are still re-profiled with the S1002 profile in the old-fashioned maintenance regime, as these trains have low axle loads and low bogie yaw stiffness.

Adopting the “HIT” wheel profile has led to a significant decrease in the occurrence of RCF cracking and flange wear of the wheel, which has resulted in an increase in the service life of the wheel of up to 30%. As the additional costs of turning a different wheel profile are minimal, a cost reduction of the same magnitude has been achieved. The impact of this alternative wheel profile on the occurrence of RCF on the rail is not known exactly. However, as noted earlier, one of the aims of the alternative wheel profile was to reduce slip forces; this means that what is beneficial for the wheel will also be beneficial for the rail.

5.2 Optimisation of wheel reprofiling intervals

Based on a life cycle cost (LCC) analysis for wheelset maintenance, for certain train types, the wheel reprofiling intervals has been successfully optimised. It entails that, at fixed intervals (based on primary train
maintenance interval), all wheels are planed preventatively, whereby about 1 mm (in depth) of metal is removed (this small metal removal rate results in a slower development of wheel out-of-roundness). This is by purpose not related on fixed number of km or tonnage to keep the extra logistics costs low. By adopting this preventative wheel planning, defect initiations, such as small cracks and pitting, are removed at an (too) early stage, thus avoiding further damage. It also results in a longer service life of the wheel (more than 10%), as compared to condition-based planning. Investigations are underway to determine whether preventative wheel planning at fixed reprofiling intervals should also be adopted for other train types, instead of the condition-based approach. Almost all NS trains have this special wheel maintenance regime (see Fig. 6) now.

Preventative wheel planing also has a significant benefit for the rail: the increased smoothness of the wheel surface achieved significantly reduces the dynamic load exerted on the rail. Preventative wheel planning, together with the use of the “QuoVadis” weigh-in-motion (WIM) system, has resulted in a reduction in the number of rail defects resulting from the operation of NS trains. A negative side effect is the smaller running band on track, because of the trains are running on “new wheel profiles” more or less. The stress concentration will be at higher density but the dynamic labour is less because of the better quality of the wheel profile itself. In the near future ProRail will analyse how the mechanism is working in practice.

**Fig. 6: Wheel planing / ‘scraping’ principle**

### 5.3 Wheel Rail Condition (WRC) development

Wheel flange lubrication (on board) is free to use for rolling stock owners in the Netherlands. NS is hardly using flange lubrication, so the ProRail network is more or less dry. This is producing much noise and squeal (yards and switches). Installation of stationary lubrication units and Top of Rail (TOR) lubrication with Friction Modifier (FM) in track proved necessary to stay within limits of the environmental legislation. Already more than 2000 units are installed in 2011, with the ambition to install 3000 units in total. The installation could be funded so far from the subsidized Dutch Innovation Programme on Railway Noise reduction.

The noise in curved rail is thus reduced by 3 Db(A), that can be marked as a big success. The negative effect is to maintain these units in a track availability environment of 7/24 hours. There is no room in track to maintain the units. A better solution must be developed and possibilities to lubricate on board get attention. It is better to talk about Wheel Rail Conditioning (WRC) than lubrication because of using a friction modifier (FM) instead of lubricants.

First goal is to reduce noise especially in curved rail, yards and switches. Beside this goal there are a number of positive side effects like wear reduction, energy saving and lifetime extension of the wheel & rail. On board lubrication is in fact the controlled use of lubrication and conditioning of the railhead (running band and side flange contact area in the gauge face) from a device installed on board on a number of the trains passing a certain piece of infrastructure. It leads to a controlled reduction in the friction (spin/slip/wear) between wheel and rails as has been proven in for instance the North American freight railways [8] and [9]. Also it is proven that it reduces the noise level.

A first pilot (started in 2009) done with Connexxion on a regional line in the middle of the Netherlands confirmed some of these results already. The pilot also demonstrated that the noise reduction is better than is the case with trackside lubrication units, which are also more complicated to maintain (logistics). A ProRail business case, made in 2010, showed the advantage of the installation of WRC.

In 2011 ProRail and NS will be starting up a pilot with each other on the main network in the east of the Netherlands as a continuation of the ProRail/Connexxion pilot on a regional line. When the success criteria from the business case are met, a roll out on the complete network may be expected after 2015. In the meantime, research work will iterate for the optimisation of the influential parameters for wheel rail conditioning. The pilot is already a success when a 4 Db(A) curving noise reduction but other positive results are more than likely: life extension of rails and wheels with a factor 2 is considered possible. Corrugations in track will disappear, thanks to using friction modifier as lubricant on top of the rails (TOR) and for flange lubrication. A net saving of 10 million Euros per year is expected as at the minimum. Extra possible advantages identified for train operators are: extension of life of wheel flanges, reduction in wheel...
flats, higher availability levels of the tracks and an improvement in friction control during autumn (slippery rails). The coefficient of friction will be more or less controlled in track and will reduce the possibilities of slippery rails during the year. Reduction of traction energy is possible with a potential of 7%, because of a lower rolling resistance.

All these parameters of the business case are real facts but need to be tested in real working conditions to know exactly how much savings there will be. The ProRail/NS pilot is monitored very intensively (on-line) by two on-board equipped measurement platforms. The first results about the amount of saving of the several parameters will be published in 2012.

Parallel to this pilot ProRail is starting up an UIC WRC working group with all experts to analyse the first results and to make also regulations about the influencing parameters of WRC. The goal of this workgroup will be to make a list of demands to specify the characteristics of on-board WRC needed. This will be the right starting point to ask the market about the possibilities to optimise the pilot results with better devices or friction modifier.
6. Conclusions and recommendations

As shown in this article, ProRail is, in close collaboration with NedTrain and NS developed a comprehensive approach to deal with risks and cost impacts of RCF, which has already led to a clear reduction in the occurrence of RCF, a reduction in noise, as well as an increase in the service life of both rail and wheel. So far, the preventative rail grinding strategy and “Anti Head Check” 54E5 rail profile which were implemented as first countermeasures have been highly successful in improving wheel/rail contact properties, reducing the occurrence of RCF defects and, thus, extending the service life of the rail. However, during the project it became clear that infrastructure-only solutions are not sufficient and that a real win-win situation can be achieved by the co-operation of Infrastructure Manager and operators in wheel/rail interface management and optimisation. This has led to 3 projects, i.e. development of a new wheel profile for intercity coaches, a new wheel planning approach and a pilot on wheel rail conditioning (WRC) - each having had clear successes already in extending life and reducing damage for both wheels / trains and rails / tracks.

Whereas railways in Europe are more and more becoming an open system with many actors involved, it remains important to seek for co-operation in a jointed design and maintenance of wheels and rails. Therefore ProRail also proposed to develop such approaches in projects through organisation as UIC, ERA and the representative bodies in Brussels, CER and EIM. It is not a time to rest on one’s laurels while new and different vehicle types cross national borders, of which the impacts need to be known and controlled. An example outside of the Netherlands of providing the right incentives for vehicle design and use is the damage-based access charges of Network Rail in the UK for bogie yaw stiffness. Further, scientific research into the wheel/rail interface will remain necessary, in order to determine other damage factors, find respective remedies and achieve closing of “open points” in the European Technical Specifications for Interoperability (TSIs) related to the wheel/rail interface.

7. References


