Abstracts of Presentations

19th Nordic Seminar on Railway Technology
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# Table of Contents

Presentations are sorted according to last name of the first author

## A

**Stiffness Variations in Track systems**

Paul Abrahamsson, Vossloh Nordic Switch Systems AB

**Improved maintenance of the wheel-rail system of Sweden’s Iron Ore Line**

Matthias Asplund, LTU and Trafikverket; Per Gustafsson, LKAB

## B

**Modern feeding methods for railways electrified with 50 – 60 Hz**

Radu Belea, Bertil Klerfors, Thorsten Schütte and Bruce Warner

**Universal Cost Model for innovative vehicle design**

Mats Berg, Sebastian Stichel and Carlos Casanueva, KTH

## C

**Numerical prediction of rail corrugation growth on curves**

Andreas Carlberger & Anders Frid, ÅF Industry AB; Peter Torstensson, Björn Pålsson & Jens Nielsen, Chalmers

**Novel articulated wagon designs for increased capacity**

Carlos Casanueva & Visakh V Krishna, KTH; Roger Jönsson, NTnet AB, Malmö; Bo-Lennart Nelldal, KTH

## D

**Crack initiation at martensite surface layers from profile grinding**

Hilmar K. Danielsen, Technical University of Denmark

## F

**Data analytics for rail maintenance management**

Stephen Mayowa Famurewa
Monitoring to extend service life of steel railway bridges
Gunnstein T. Frøseth, Anders Rønnquist and Ole Øiseth, NTNU

Consequences regarding an increase of the axle load in heavy haul operation in a test period on Ofotbanen
Hallstein Gåsemyr, JBV

Weather related train delays
Peter Hagberg, Göteborgs Universitet

Making Big Data Risk Analysis work for the GB Railways
Peter Hughes, University of Huddersfield

Lessons learned from the ePilot – railway development and innovation project
Ulla Juntti, Veronica Jägare

Service management 4.0 och dess applicerbarhet i svensk järnvägsindustri
Mirka Kans and Anders Ingwald, Linnéuniversitetet

Track irregularities and vehicle response
Tomas Karis, Mats Berg & Sebastian Stichel, KTH

Effects of Top-Of-Rail Friction-Modifier (TOR-FM) on wear, cracks and friction
Saad Ahmed Khan, LTU

Efficient coordination of railway infrastructure activities
Martin P. Kidd, Richard M. Lusby and Jesper Larsen, Technical University of Denmark
<table>
<thead>
<tr>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>A mathematical model for train wheel maintenance</td>
<td>19</td>
</tr>
<tr>
<td>Efraim Laksman, Ann-Brith Strömberg, and Michael Patriksson, Chalmers</td>
<td></td>
</tr>
<tr>
<td>University of Technology</td>
<td></td>
</tr>
<tr>
<td>Under Sleeper Pads on the Ofoten Line</td>
<td>20</td>
</tr>
<tr>
<td>Bjørn Gunnar Larsen, Alf Helge Løhren, Jernbaneverket</td>
<td></td>
</tr>
<tr>
<td>Using trains in traffic for condition monitoring of infrastructure –</td>
<td>21</td>
</tr>
<tr>
<td>results from demo, examples from catenaries, and implications for</td>
<td></td>
</tr>
<tr>
<td>further innovation.</td>
<td></td>
</tr>
<tr>
<td>Peter Larsson, Trafikverket; Peter Melander, UPPSAMT</td>
<td></td>
</tr>
<tr>
<td>Heavy transport on existing lines: the assessment of bearing</td>
<td>22</td>
</tr>
<tr>
<td>capacity of track-bed based on track stiffness measurements and</td>
<td></td>
</tr>
<tr>
<td>theoretical studies</td>
<td></td>
</tr>
<tr>
<td>Martin Li, Alexander Smekal, Trafikverket</td>
<td></td>
</tr>
<tr>
<td>New Concept for Higher Speed on Existing Catenary System: Auxiliary</td>
<td>23</td>
</tr>
<tr>
<td>Pantograph Operation</td>
<td></td>
</tr>
<tr>
<td>Zhendong Liu &amp; Sebastian Stichel, KTH</td>
<td></td>
</tr>
<tr>
<td>Hand held appartus for friction and wear mesurements of railway tracks</td>
<td>25</td>
</tr>
<tr>
<td>Jan Lundberg</td>
<td></td>
</tr>
<tr>
<td>The influence of corrugation on tangential forces and rolling</td>
<td>26</td>
</tr>
<tr>
<td>contact fatigue</td>
<td></td>
</tr>
<tr>
<td>Roger Lundén, Jens Nielsen and Anders Ekberg, Chalmers</td>
<td></td>
</tr>
<tr>
<td>The Swedish procurement strategy – a literature review</td>
<td>27</td>
</tr>
<tr>
<td>Jens Modig, LTU</td>
<td></td>
</tr>
<tr>
<td>Wheel life prediction model considering wear and RCF: LKAB Iron-Ore</td>
<td>28</td>
</tr>
<tr>
<td>Loco</td>
<td></td>
</tr>
<tr>
<td>Saeed Hossein Nia, Carlos Casanueva &amp; Sebastian Stichel, KTH</td>
<td></td>
</tr>
<tr>
<td>Title</td>
<td>Page</td>
</tr>
<tr>
<td>----------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>Increased Axle Load to 32.5 tonnes – what Operational and Maintenance effects will it have for the Rolling Stock?</td>
<td>29</td>
</tr>
<tr>
<td>Thomas Nordmark, LTU</td>
<td></td>
</tr>
<tr>
<td>A case study on Railway Infrastructure Robustness for Switches and Crossings</td>
<td>30</td>
</tr>
<tr>
<td>Per Norrbin, Sweco Rail AB; Jing Lin, LTU</td>
<td></td>
</tr>
<tr>
<td>Estimation of wheel-rail friction at vehicle certification measurements</td>
<td>32</td>
</tr>
<tr>
<td>Marton Palinko, Mats Berg, KTH; Lars Andersson, SNC Lavalin</td>
<td></td>
</tr>
<tr>
<td>Passenger train delays in southern Sweden</td>
<td>33</td>
</tr>
<tr>
<td>Carl-William Palmqvist, Teknik och Samhälle på LTH</td>
<td></td>
</tr>
<tr>
<td>Working together to find better solutions: Methods facilitating collaboration in the context of a deregulated railway market</td>
<td>34</td>
</tr>
<tr>
<td>Anna Malou Petersson, LTU</td>
<td></td>
</tr>
<tr>
<td>Dynamics of SCA Logistics Wagons and its Influence on Wheel Damage</td>
<td>35</td>
</tr>
<tr>
<td>Robin Prevolnik, Carlos Casanueva, Saeed Hossein Nia, KTH</td>
<td></td>
</tr>
<tr>
<td>Kinematic Principles in Switches &amp; Crossings</td>
<td>36</td>
</tr>
<tr>
<td>Björn Pålsson, Chalmers</td>
<td></td>
</tr>
<tr>
<td>A Novel Flowchart for Studying Active Suspension Failures in Rail Vehicles</td>
<td>37</td>
</tr>
<tr>
<td>A. Qazizadeh &amp; S. Stichel, KTH; R. Persson, Bombardier Transportation</td>
<td></td>
</tr>
<tr>
<td>Structural challenges with railway catenary systems</td>
<td>38</td>
</tr>
<tr>
<td>Anders Rønnquist &amp; Petter Nåvik, NTNU</td>
<td></td>
</tr>
</tbody>
</table>
EN 14363:2016 – a new and feasible way of homologating vehicles from a running dynamics point of view
Mikael Wrang, MiW Rail Technology AB

Sliding Window-based Fault Detection from High-dimensional Data Streams
Liangwei Zhang, LTU
Stiffness Variations in Track systems

19th Nordic Seminar on Railway Technology 14-15 September

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Abstract

The stiffness variation in track system is an old and well known problem. It has become a more significant problem area as axle loads are rising, high speed track system is in focus but also in urban areas where noise and vibration is a concern both in old track structures and when new ones are designed.

To design and build a track system that can even out the stiffness variation, there are some different ideas about how to do it and what the limitations are and how complexed it has to be.

In the end there is a need for a design that will minimize maintenance and when the track structure transfer from bridges with or without ballast to a ballasted track, from slab track to ballasted track and other stiffer construction in track as for example large Switches.

The presentation will focus on why transition zones are needed and some example of how it can be done
Improved maintenance of the wheel-rail system of Sweden’s Iron Ore Line

19th Nordic Seminar on Railway Technology 14-15 September 2016

Matthias Asplund*, Luleå University of Technology and the Swedish Transport Administration

Per Gustafsson, LKAB

Abstract

The Swedish Iron Ore Line (IOL) is the only heavy haul line in Europe. The IOL is a 473 km long track section located in northern Sweden and northern Norway, and has been in operation since 1903. The northern part of the line is located above the Arctic Circle, which means a very harsh climate. The IOL is mainly used to transport iron ore and pellets from the mines in Kiruna and Malmberget to Narvik Harbour (Norway) in the northwest and Luleå Harbour (Sweden) in the southeast. The track section on the Swedish side is owned by the Swedish Government and managed by the Swedish Transport Administration (Trafikverket), while the ore trains are owned and managed by the mining company and freight operator LKAB.

The capacity of the line has been problematic, and therefore the IOL has seen a considerable increase in the axle load, the train length and the traffic volume recently. Due to the introduction of new vehicles with a 30-ton axle load, the rails were gradually replaced between 2006 and 2009 with heavier rails, generally with a steel grade of 350LHT. Just after the first replacement of track in 2006, the project presented herein was established with the primary goal of improving the life length of the rail, and monitoring activities started. This project then broadened its scope to consider not only the rail, but also the wheel-rail system. The project group consists of members from the Swedish Transport Administration, the Norwegian Transport Administration, the rail maintenance supplier, the rail supplier and the freight operator. This project has now a unique database containing rail degradation data due to the careful monitoring activities performed on the rail. So far the information has been used to improve the performance of the wheel-rail system and thus extend the life length of the rail, as well as to improve our knowledge of heavy haul operations in a cold climate.

This presentation shows the actual operational conditions of the IOL, at the start of the project and during the project. Then the presentation shows the project progress in general and some good examples of improvements that have been successfully implemented. Finally, the presentation discusses the challenges of future capacity improvements, such as a further increase in the axle load, and how these can be addressed.

* Presenter
Modern feeding methods for railways electrified with 50 – 60 Hz

Railway electrification with 50 or 60 Hz is today the most common solution as it can be realized without frequency converters or rectifiers by using transformers directly linking the public power grid with the railway catenary. Today this system, based on feeding the railway with single phase transformers connected between phases of the public grid increasingly meets its limits. On the one hand, the power needed from the railway increases due to higher power for each train, denser traffic and higher speed. On the other hand, the shift to renewable power sources and decentralized power generation and subsequent decommission of large fossil or nuclear power plants, reduces the short circuit power in the grid limiting the unbalanced single phase load acceptable for the public grid.

For new electrifications there exist both improved compensation circuits and frequency converters as proper solutions of the problem. For already existing AC electrified railways and feeding stations there is a lack of solution which to a large extend can reuse already installed equipment, especially single phase transformers. Compensation circuits according to the Steinmetz scheme can theoretically derived from two single phase transformers completed by a third one in delta or Y connection. Both solutions have distinct disadvantages as insulation levels or zero sequence components.

Here an alternative Steinmetz connection is proposed by using three single phase transformers in a “W”-connection with the phases 0, 60 and 120 degrees. For a feeding station in V-connection, the existing two transformers are reused and a third one is added. With the same compensation inductances and capacitances as for the classical Steinmetz scheme, the compensation problem is now solved with standard single phase transformers for low insulation level on the rail side which can be reused. Additional compensation for power factor can easily be integrated, e.g. as series compensation in the middle “leg” of the “W”.

Universal Cost Model for innovative vehicle design

Mats Berg, Sebastian Stichel and Carlos Casanueva

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Abstract

In the development of enhanced rail vehicle designs the added benefits are sometimes difficult to motivate from an economical perspective. This is often due to a higher initial vehicle cost while the benefits are spread over the entire vehicle life and are more difficult to quantify. This calls for a Life Cycle Cost approach, but which still seems to be hard to adopt in many rail organisations.

In the ongoing European project Roll2Rail, a pre-project to the extensive research programme Shift2Rail, this issue is taken on focussing on innovative bogie designs (Work Package 4). Partners in WP4 mainly represent vehicle manufacturers and vehicle operators, but also infrastructure managers like Trafikverket and academic organisations like KTH. WP4 is led by Bombardier Transportation.

To balance or preferably exceed the higher initial cost, and associated capital cost, four types of other costs are studied in detail: vehicle maintenance cost and the vehicle operational costs for energy, noise and track access. For separated railways the track access cost for a vehicle operator originates from a charge imposed by the infrastructure manager. Unfortunately this charge seldom acknowledges improved vehicles designs that offer reduced track maintenance and external noise.

The WP4 work is setting up a framework, a so-called Universal Cost Model, where the above cost components are included, with the aim to simplify LCC calculations and support innovative vehicle designs. A challenge is to connect technical improvements and results into economical quantities.

The seminar presentation will provide further insight into this work and welcomes further input to the ongoing efforts in Roll2Rail WP4.
Numerical prediction of rail corrugation growth on curves

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Rail corrugation (periodic surface irregularities at distinct wavelengths) is a problem experienced by many railway networks worldwide. Corrugation induces a pronounced dynamic wheel–rail contact loading that leads to increased generation of noise and in severe cases even damage to vehicle and track components. The large magnitude creep forces and sliding between wheel and rail make corrugation especially prone to develop on curved track. The current work summarizes the results from a Master Thesis project performed in collaboration between Chalmers, ÅF Industry, Bombardier Transportation and Stockholm Public Transport.

A time-domain model for the prediction of long-term growth of rail roughness has been developed, see Figure 1. Dynamic vehicle–track interaction in a broad frequency range (at least up to 300 Hz) is simulated using the commercial software SIMPACK. Wheelset structural flexibility is accounted for by using modal parameters calculated for a finite element model. Non-Hertzian and non-steady wheel–rail contact and associated generation of wear are calculated in a post-processing step in the software Matlab. Archard’s law is applied to model the sliding wear. A large number of train passages is accounted for by recurrent updating of the rail surface irregularity based on the calculated wear depth. The proposed prediction model is applied to investigate a curve on the Stockholm metro network exposed to severe corrugation growth.

Figure 1. Illustration of the iterative numerical procedure for prediction of long-term rail roughness growth
Novel articulated wagon designs for increased capacity

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Abstract

Capacity4Rail is a EU project whose aims are improving the competitiveness and reliability of rail freight in order to make it more attractive more sophisticated and modern market requirements. This work focuses on increasing the capacity of the overall system by using novel vehicle designs with higher payload per meter, both from the system design and the vehicle dynamics point of view. The proposal is to design an articulated spine wagon composed by five car bodies and six bogies, of which four of them are shared between one car body and the next one. In the work package, an effort has been made to look into the implications of these type of very long wagons in all aspects of freight operation, and this presentation focuses on three of these aspects: the increase in payload by using different but related configurations, the challenges in vehicle design, and the dynamic analysis of the running gear. From vehicle performance point of view the conclusion is that it is worth to explore the possibility of increasing payload by slightly worsening the dynamic behavior of the train set.
Crack initiation at martensite surface layers from profile grinding

Hilmar K Danielsen, Technical University of Denmark

Cracks from rolling contact fatigue on rails have been found to be associated with thin martensitic layers that form from thermal exposure, such as profile grinding. Rails that had just been subjected to profile grinding were investigated, and were seen to be covered by a martensitic surface layer as a result of the developed heat from grinding. Worn rails that showed bands of martensitic layers that resemble grinding marks have been found in the Danish rail network, both on soft and head hardened steels. Sections of such rails have been extracted and investigated using optical microscopy and 3D X-ray computerised tomography. Periodic cracks starting at the martensitic layers which resemble grinding marks were found, showing a possible connection between profile grinding and crack initiation.

For identifying martensitic layers on top of the rails, an etching procedure was used with 3% nital which attacks the pearlite bulk but leaves martensite layers unaffected. This gives a good contrast for identifying martensitic bands on the rail surface. While martensite marks from braking or accelerating trains appear as continuous bands on top of the rails, there were instances where periodic transverse martensite bands resembling grinding marks were found, typically between the gauge corner and the top of the rail. Optical microscopy of these bands showed them to be local martensitic layers with varying depths, up to 0,05mm, which corresponds to the depth of martensite caused by profile grinding. Cracks of varying sizes and stages were found in conjunction with the martensitic layers. 3D mapping of surface cracks using X-ray tomography showed cracks could extend along the whole front of the martensite band, indicating the crack initiation point to be at the martensitic/pearlitic interface.
Data analytics for rail maintenance management

Stephen Mayowa Famurewa, Luleå University of Technology

The wear of rail is considered to be a critical degradation mode in heavy haul transport, thus rail wear are keenly studied with dynamic simulation models, contact theories, field measurement data and other methods. This study presents a framework for rail data analytics that is useful for rail maintenance management using measurement data. An example is the assessment of rail condition with respect to wear phenomenon. The framework covers three essential maintenance aspects: diagnostic, predictive and prescriptive aspects. Furthermore, a use case is presented to demonstrate the use of PCA (Principal component analysis) as a diagnostic tool for detection of anomalous rail wear.
Monitoring to extend service life of steel railway bridges.

Gunnstein T. Frøseth, Anders Rønnquist and Ole Øiseth
Department of Structural Engineering, NTNU.

Construction of the Norwegian railway network in 1850 and expansion of the railway network continued throughout the 19th century before it was largely completed in 1964 with Nordlandsbanen reaching Bodø. Steel was the preferred choice as construction material in the period up to the second world war and today the railway network consists of 2700 bridges of which 1000 are steel bridges. Fatigue was not considered in design of steel structures until the end of world war II and therefore most steel bridges in the Norwegian railway network was never designed for this failure mode.

Remaining service life of steel railway bridges is assessed in a stepwise manner, where each step involves increasing complexity and more resource use. The assessment goes through an initial assessment where the goal is to establish whether fatigue is a relevant issue for the structure. Components and details which fail the first step, are taken through deterministic, and subsequently, probabilistic assessment based on damage accumulation theory, which estimates the remaining service life of the structure. Conservative assumptions on the input variables typically lead to gross underestimation of remaining service life. Additionally, uncertainties associated with loading, structural response and fatigue resistance is reflected in the accuracy and precision of the final assessment of remaining service life. Sensitivity analysis reveals that model uncertainty is typically dominant in the uncertainty of the overall assessment. Model uncertainty may be reduced by carrying out measurements on the structure. The ultimate step in the assessment procedure therefore involves field measurements to omit the uncertainty associated with simulations and analytical models entirely.

Ongoing research at the Department of Structural Engineering, NTNU, aims to determine the number of measurement points and also the location of measurement points to ensure that the appropriate decision regarding the remaining service life of steel bridges is made with accurate and reliable information. A measurement system with 56 strain channels will be mounted on the crossgirders, stringers and the connection between these components on the Hell Bridge located just north of Hell station. The Hell Bridge is a riveted steel bridge consisting of five identical spans each with a theoretical width of 35m. The structure is a typical parker pony truss bridge found in the Norwegian railway network, and in bridge stock all around the world. The measurement system will monitor the bridge for a minimum of 60 days to increase the
likelihood that critical axle loads and associated strains are captured in the measurement period. The goal of the measurement campaign is to:

1) determine the variability of measured strains in nominally identical components.
2) quantify model error in finite element models of the bridge utilized in fatigue assessment of critical components
3) develop a rational and efficient procedure for asserting sufficient service life of these bridges through measurements.

The research has high practical value because it addresses both the initial, intermediate and the ultimate steps in modern assessment of steel railway bridges by quantifying model uncertainty, which can be used in assessment on similar bridges, and providing guidelines for efficient measurement campaigns.
Abstract for the 19th Nordic Seminar on Railway Technology in Luleå

Consequences regarding an increase of the axle load in heavy haul operation in a test period on Ofotbanen

The topic will focus on the recent market downturn characterized by low commodity prices and slowdown in demand for freight bulk operation such as coal or iron. In order to contribute and respond to this fact as far as the operational conditions for the heavy haul operations are concerned, Jernbaneverket is making a study whether the existing axle load of 30 tonnes can be increased up to 32.50 tonnes for one train only per day in a test period as a cautious start for experience purposes.

The Norwegian part of the iron ore line from Swedish border to Narvik harbour has a length of 42 kilometers with a challenging track geometry consisting of small curve radii, a longitudinal falling gradient with an average of 17 mm/m as well as a demanding track construction (permanent way).

A standard for approval of new vehicles with axle loads higher than 25 tonnes and up to 35 tonnes based on EN 14363 has been worked out by Jernbaneverket and Trafikverket together with MiW Rail Technology in Stockholm. Maximum lateral and vertical forces will be dealt with.

At the location of Haugfjell track forces from vehicles with 30 tonnes axle load in normal conditions are being measured applying a Damill Wayside Inspection Devices System. Extracts of measured forces will be shown.

Based on measured track forces for 30 tonnes axle load on the iron ore line being evaluated and calculated according to the principles of EN 14363 considerations of stresses on the track construction for 32.50 tonnes will be carried out.

Cumulative distribution for longitudinal level and for alignment on Ofotbanen will be shown according to Optram measurement system.

The topic will further set focus on whether a certain upgrade of the infrastructure will be necessary or whether an increased inspection and maintenance regime is sufficient. As far as the track is concerned, a lot of parameters have to be dealt with. Among them are:

- Rails, rail fastenings, sleepers, ballast bed, irregularities on rails and wheels, wheel/rail contact mechanics, creepage and creep.

The parameters related to the interaction of wagon and track aspects contributing to high, moderate and low effect on fatigue issues due to the minor increase of the axle load will be identified.

Finally, based on these studies the question will be asked how to work smarter as far as maintenance issues on the line are concerned.
WEATHER RELATED TRAIN DELAYS

PETER HAGBERG

ABSTRACT. Understanding how severe weather situations disrupt railway traffic could be of great benefit to a methodological, passenger oriented handling of such situations, yet documentation of correlations is scarce. This initial method study, with focus on the effect of storms and blizzards, was undertaken to enable optimised handling of difficult weather and to empirically answer the question of when weather becomes disruptive. The geo-referencing of delay reports enabled correlation analysis with a meso-scale meteorological model. Regional comparisons between total amount of delay and severeness of conditions, indicated by wind speed and amount of snowfall, revealed clear trends but also large variability. Although risk and size of delay increased as conditions got more severe, there were no conditions under which major delays could not occur. The train delay reports do not discriminate between cases where weather induced obstacles disrupted traffic and cases where traffic was restricted out of precaution, nor do they separate isolated incidents from collective, regional reports. This impedes an evaluation of the present praxis for cautionary measures. A provisory division based on keywords occurring in the comments provided some additional insight. Delays related to warnings and safety measures mainly occurred under severe conditions, whereas tree related incidents could occur under any conditions, but mainly at moderate to fresh wind speeds. This indicates that wind speed as a factor is subordinate to tree management. For actual storm events, the introduction of a systematic approach, as implemented in this study, showed great potential in terms of enabling a more passenger oriented handling, as it would allow well informed decisions to be made at an earlier stage.
Making Big Data Risk Analysis work for the GB Railways

Keynote by Peter Hughes

Institute of Railway Research, University of Huddersfield

The systematic management of safety risk on the GB railways is currently underpinned by the Safety Risk Model: a complex suite of fault tree models that describe the railway’s key safety risks, their causes and controls, and estimates of the expected frequency of occurrence of each event. Whilst these fault trees provide a valuable method of managing safety, keeping a large number of fault trees up-to-date is a slow and laborious task.

With modern technology it is easy to envisage a system that would automatically integrate data from a very large number of sources, including electronic sensors, audio and video data, text-based incident reports, and external sources such as weather reports and social media. Combining such data sources could give a real-time picture of risk on the railway, and allow safety analysts to understand the complex interaction of precursors that lead to hazards arising, as well as understanding the subtleties in the behaviour of controls that reduce the likelihood of accidents occurring on the railway.

Combining large amounts of data brings with it problems that are not prevalent with the existing SRM: how to respond to interruptions in data streams; how to resolve conflicting data; or how to extract data from sources such as freeform text? Huddersfield University, in conjunction with the Rail Safety and Standards Board, is researching a new approach to providing real-time safety information for the railway industry: Big Data Risk Analysis (BDRA).

The approach uses bow-tie models as the underlying model of safety on the railway, but incorporates real-time information within an ontology that defines the components of the railway and their interaction with each other. As new technology brings new data sources, these sources can be integrated within the ontology; as the operations and risks on the railway change over time, these changes are reflected in an updated ontology. Interactive visualisation techniques are designed to allow users to incorporate their own knowledge and experience to update the underlying safety model. The aim of BDRA is to create a model that contains not only the data, but also the core knowledge on how to manage safety on an increasingly complex railway system.
Lessons learned from the ePilot – railway development and innovation project

Ulla Junntti 1 and Veronica Jägare 2

1 Performance in Cold, 2 LTU

Abstract

ePilot is an eMaintenance pilot project with the objective to implement results from research and development into the Swedish Rail. The aim is to use different types of condition data to develop decision support using preventive measures to minimize disruptions of the railway system in a cost effective manner. The projects corner stones are enhanced collaboration amongst all involved parties, a neutral platform, a framework with play rules and a eMaintenance system for integrating access to a central computerised data analysis carried out in line with both the customer and the supplier’s business goals and intrinsic components in all parts of a system’s life cycle.

ePilot and eMaintenance has been implemented in a project called ePilot119 in the northern part of Sweden on track section 119 between Luleå and Boden. The project started in the autumn of 2013 and will be finished in February 2017.

Lessons learned so far are: There is a large need and demand for enhanced collaboration and sharing of maintenance decision support within the Swedish Railway. Several of the ePilot119 subprojects have shown big potential and good results of creating common decision support tools and implementing new innovations. It has also shown how important it is to present the benefits, potential and bringing the participants together “on the same train”.

However there are a lot of barriers that needs to be dealt with in order to implement and gain the results, amongst them rules, regulations and contracts.

An important experience has been that the quality of the data supplied is not always reliable, e.g. incomplete calibrating of equipment, which has led to new procedures and methods being developed to assure the quality of data, and clear the corrupt data that existed in the data cloud.

Another lesson learned is the difficulties to find resources for conducting the work, due to slim organisations together with limited time in track to perform tests.
Sammanfattning. Industri 4.0 fokuserar på att leverera avancerade tekniska lösningar till tillverkningsindustrin såväl som andra industrisegment, men för att dessa tekniska innovationer ska lyckas måste de koordineras med och reflekteras i de strategiska affärsmodellerna. Ett ramverk för affärsmodellutveckling har därför tagits fram som reflekterar den tekniska utvecklingen och dess servicebehov från den första industriella revolutionen och framåt utifrån ett verksamhetsmodelleringsperspektiv genom att omvandla underhåll från att vara en teknisk produkt till en värdeskapande aktivitet. Den fjärde fasen kallar vi Service Management 4.0. Service Management 4.0 fokuserar på de insatser som krävs för att leverera värde till kunden, och därigenom blir det tydligt att underhåll måste ses som en värdeskapande aktivitet, och inte bara som en kostnadsfaktor som bör minimeras. Service management 4.0 inriktar sig därmed på värdeskapande för de berörda aktörerna, medan Industri 4.0 och Underhåll 4.0 är inriktade på teknisk prestanda. Detta bidrag beskriver begreppet Service Management 4.0 och diskuterar dess applicerbarhet i svensk järnvägsindustri. Mer specifikt kommer koncepten partnering, affärskosystem, buntade erbjudanden och prestationbaserade kontrakt att diskuteras.

Service Management 4.0 and its applicability in the Swedish railway industry

Abstract. Industry 4.0 focuses on delivering advanced technological solutions for the manufacturing industry as well as other industry segments, but for these technological innovations to succeed, they must be coordinated with and reflected in the strategic business models. A framework for business model development has therefore been developed reflecting the technical development and its service needs from the first industrial revolution onwards from a business modelling perspective by converting maintenance from being a technical product into a value-creating activity. The fourth phase is called the Service Management 4.0. Service Management 4.0 focuses on the actions required to deliver value to the customer, and thus it becomes clear that maintenance must be seen as a value-adding activity, and not just as a cost factor that should be minimized. Service Management 4.0 is therefore about value creation for stakeholders, while Industrial Maintenance 4.0 and 4.0 focus on technical performance. This contribution describes the concept of Service Management 4.0 and discusses its applicability in the Swedish railway industry. More specifically, the concept of partnering, business ecosystems, bundled offerings and performance-based contracts will be discussed.
Track irregularities and vehicle response

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Abstract

When building or maintaining a railway track, there is a theoretical (nominal) track geometry to follow. Since it is not possible to perfectly follow the nominal geometry, there will be some deviations from it, usually called track irregularities. The measured level of deviations from the nominal geometry is often linked to a track quality level. Generally higher vehicle speed requires a higher quality level. This is because track irregularities have a large impact on the dynamic response of a vehicle. However, the connection between track quality and how the vehicles react is not always clear. In terms of correlation there is often a large variation for different vehicles and operational conditions, which is observed in recent studies.

The present research project aims at resolving some of the questions regarding how rail vehicles react to track irregularities. The end result will hopefully give a clearer view on how to define track geometry quality and also a better understanding of what has most impact on vehicle response. Thus, this should also benefit normative and informative standards as well as improve maintenance efforts in track infrastructures and be of benefit for vehicle acceptance testing.

Currently the most common way to evaluate track geometry quality is filtering in the wavelength domain, followed by a statistical evaluation involving maximum values or standard deviations. There are also a few methods involving dynamic simulations for different vehicle types to evaluate if the track geometry quality is within certain limits. For vehicle response evaluation it is common practice to filter e.g. wheel-rail forces and bogie or carbody accelerations in the frequency domain and then look at mainly maximum values and mean values over certain sections. In previous studies it is concluded that these methods give reasonable results, but cannot explain the complete relation between track irregularities and vehicle response.

In this first part of the project a Matlab code has been written to evaluate different measurements of track irregularities and vehicle reactions. The measured data is analysed to identify track sections (tangent track, curved track, transition curves etc.) according to EN 14363. For each track section, the corresponding vehicle reactions are then analysed. Currently the focus is on what happens in the vertical direction. The analysis is used to compare measurement results from two research projects: the Swedish Gröna Tåget and the EU project DynoTrain. By using data from two separate sets of measurements, it should be possible to pin-point what information is important for the track-vehicle interaction and what information can be considered as noise or disturbances. The disturbances might be variation in track stiffness (e.g. sleepers, slab track, bridges) or non-linearities that are not accounted for. The vehicles included in the comparison are a locomotive, a passenger coach and an electric multiple unit (EMU). Preliminary results give a similar picture as in earlier studies, where the correlation between vertical track irregularities and vertical wheel-rail forces vary for the different cases, e.g. variation in speed, vehicle type, wheel position in vehicle and track irregularity wavelength range. Another conclusion is that it is important to remove or compensate for the disturbances indicated above.

Keywords: track geometry quality, track irregularities, vehicle acceptance, vehicle response, wheel-rail forces, dynamic simulations

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Effects of Top-Of-Rail Friction-Modifier (TOR-FM) on wear, cracks and friction

Abstract:

Rolling contact fatigue (RCF) and wear are major problems with railway tracks, especially on curves, which lead to higher maintenance costs. By optimizing the top of rail friction, the traction forces which cause wear and cracks on the top of rail, can eventually be reduced, without causing too long braking distance. The use of top of rail friction modifier (TOR-FM) was first published in 2003, has come up as a possible solution to control these traction forces. The TOR-FM is a product which according to the manufacturers claims to control the friction coefficient, in a certain range (0.3-0.4), between the rail head and wheel tread. The TOR-FM has been tested and implemented in several North American and Chinese heavy haul freight railway sites.

Malmbanan iron ore line situated in the North of Sweden, is mainly used for transporting iron ores from the mines in Kiruna and Malmberget to the seaport in Lulea, Sweden and Narvik, Norway. Till date, no TOR friction control has been implemented and RCF and wear are major problems with the railway line, especially on curves. By using the TOR-FM traction forces between the railway line and wheel can be eventually controlled, which in turn can minimize the wear and cracks. But Trafikverket (infrastructure manager in Sweden) is still sceptical about the use of top of rail friction modifier, as technical and economic efficiency of this product is unknown for the Swedish conditions.

To study the effects of TOR-FM and calculate the savings by using TOR-FM for Swedish heavy haul conditions, field tests (on Malmbanan iron ore line) and simulations are being carried out. For field tests, two similar curves having radius 394 m and 395 m are selected. At one of the curves (395 m), wayside TOR-FM equipment has been installed and the other curve (394 m) will remain without friction modifier (reference curve). Field test, which includes profile measurement, crack detection, friction and roughness measurement, will be carried out at a particular time interval for three years, to study the effect of TOR-FM. As the field tests require approx. 3 years, which is too long, the waiting time for the field test results is utilised to perform multibody simulation (GENSYS software). Simulations are performed by using available field inputs, which will also be validated with the field measurement. In the last, life cycle cost will be calculated by using both field test and simulation.

Until now it is hard to make any concrete statement about the benefits and drawback of friction modifier. But the stationary wayside equipment does not seem to be a solution for heavy haul track in Sweden, as it has lots of issues due to snow and extreme winters and it may lead to very high maintenance and operating cost. However, the simulations have shown a reduction in both wear and probability of cracks generation by controlling the friction control (stable friction values lower than dry condition). From the theoretical point of view, it can be concluded that controlling the top of rail friction is a good method to reduce wear and cracks, but an alternative a method (may be Auto pilot system mounted on the train) for application of friction modifier is needed for economic efficiency.
Efficient coordination of railway infrastructure activities

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A major concern when it comes to the management of railway infrastructure activities such as maintenance and renewals is its inherent conflict with the paths of freight and passenger train services. An important objective for the infrastructure manager is therefore to limit the discomfort experienced by users of these services, especially daily commuters, due to the disruptions caused by infrastructure activities. One way in which the disruptive effects of infrastructure projects can be limited is to schedule as many activities as is technically possible simultaneously on the same part of infrastructure. Doing so will require fewer track possessions and therefore fewer disruptions to daily train operations.

However, even though performing many different activities simultaneously on the same part of infrastructure is often technically possible, it naturally gives rise to peaks in resource consumption. This relates to a well studied topic in project scheduling known as resource levelling that focusses on the efficient utilization of resources by minimizing fluctuations in resource consumption. It follows that there exists a tradeoff in terms of efficiency when it comes to scheduling railway infrastructure activities, namely between limiting the effects of disruptions caused and the balancing of resource consumption over the scheduling horizon.

In this talk we study this tradeoff from a mathematical modelling point of view, and we present an optimization algorithm based on mixed integer linear programming to assist in the scheduling of infrastructure projects and activities. The algorithm aims to produce schedules with a smooth resource profile while keeping the number of possessions low and/or sparse in time. Computational experiments are performed using data on infrastructure projects made available by Banedanmark, the main railway infrastructure manager of Denmark. We show that the algorithm produces good results in short computation times, and that it shows promise as a decision support tool for the management of railway infrastructure projects.
A mathematical model for train wheel maintenance

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During use train wheels become worn and damaged, and may cease to satisfy security restrictions on profile, diameter, and diameter differences between wheels. The profile of a wheel can be restored through lathing, but this activity reduces its diameter, which may call for lathing also of other wheels in order to retain acceptably small differences in diameters. As the restrictions on the differences between diameters of wheels depend on their relative positions on the train, a relocation of axles (i.e., pairs of wheels) may reduce the need for lathing. Relocations of axles can be made within the train, and between the train and a spare inventory of (new and used) axles.

The goal is - for each train and maintenance occasion - to decide on a relocation of axles and a lathing of the wheels, such that a sum of direct and (expected) future costs is at minimum, while keeping the value of the train as well as of the inventory high. We construct and solve a mixed binary linear optimization model of this problem.

This work is performed within the Vinnova project Future Industrial Services Management, as a case study for and with the project partner EuroMaint.
Abstract to 19th Nordic Seminar on Railway Technology 2016 in Luleå

UNDER SLEEPER PADS ON THE OFOTEN LINE

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Alf Helge Løhren, Civil Engineer PhD, Technology Track Engineering, Jernbaneverket

The first Under Sleeper Pads (USP) put to use on the Ofoten line about 2000, were on concrete bearers for switches. The next sleepers with USP were installed in the main track on Straumsnes station in 2012. In a curve with radius 322 m 627 wooden sleepers were replaced by concrete sleepers JBV60 of which 567 had USP from Getzner type SLB 2210 ($C_{stat} = 0.22 \text{ N/mm}^3$, thickness 10 mm). Norwegian National Rail Administration (Jernbaneverket - JBV) wanted to gain experience with USP on a Heavy Haul line where maximum axle load is 30 tons.

JBV started a follow-up project together with Northern Research Institute (NORUT) and Norwegian Railway Technology Centre (NorJeTS), but stopped at the turn of the year 2014/2015. Due to short test period the basis to draw definitive conclusions were limited. USP seem to have a positive influence on track geometry maintenance and reduced rail wear.

Nevertheless JBV wants to know more about how the USP behave and develop, and the last two years new concrete sleepers with USP are installed in two rehabilitated and extended station areas, respectively Rombak and Bjørnfjell. JBV considers to have USP as standard on all concrete sleepers on the Ofoten line, and wants to get more information about what influence the USP may have on the track construction and of course the lifetime to the USP on a Heavy Haul line. The oldest USP on the Ofoten line have been exposed to a traffic volume of approximately 100 MGT on Straumsnes.

To evaluate the condition of these USP, JBV will remove some concrete sleepers both with and without USP in the summer 2016 and assess visual the USP itself and eventually size reduction of the ballast under the sleepers after 100 MGT. Besides JBV will compare track geometry measurements to investigate if USP have any influence on track geometry quality, e.g. tamping intervals. Possible influence on development of rail corrugation in small curve radii is also of interest to investigate.

JBV has also started working with another test program for use of USP on the Ofoten line. In new tests JBV considers to use monoblock “Smart sleepers” with imbedded censors to measure loads, tensions and bending moments in the sleeper. The “Smart sleepers” shall be with and without USP and USP from different suppliers. They will be installed in a track with operation. This will give both immediate and long-term results.
Abstract


Title: Using trains in traffic for condition monitoring of infrastructure – results from demo, examples from catenaries, and implications for further innovation.

Peter Larsson, Trafikverket / Peter Melander, UPPSAMT

The technology needed to implement Digitalization in Rail has been more or less ready for the last 10-15 years. Yet not much has been implemented. The innovation challenge is often not technology, but rather organisational development, and development supported by new technology.

In each country the innovation and implementation challenge will be different. In Sweden our challenge and success has been good Collaboration and Cooperation together with the different organisation in the deregulated Swedish rail transport industry, including the different owners of the fleet of vehicles in Sweden.

During the last year Trafikverket has launched an initiative to jointly develop a concept ("UPPSAMT", or simply "Connected2Rail") and run a demo-project. The demo-project has achieved its main goal: To create an appetite and acceptance for increased digitalisation and new tools among those in railways in general, and in asset monitoring and management in particular. Manifested in trivial but real forms:

- Demo-data are already now being uploaded to the database (Optram) dedicated to the Measuring-Vehicles. This type of “Data Fusion” has provided new knowledge about the condition of the infrastructure. In fact, maintenance staff has been called out to adjust and repair catenaries based on demo data.
- The Asset Monitoring department and Traffic Control centre has decided that new operation-leaders shall be trained in the use of the concept and the (early stage) tools developed.

The tactics of the initiative is to go step-by-step, initially limited to catenaries and a subset of operators. (Many initiatives have failed by trying to do everything at once, or the difficult things first).

The initiative and concept will this year be developed further, selected as a part of a new project driving the Digitalisation Strategies within Trafikverket and rail transport. The presentation will provide details findings regarding the collaboration between our catenaries and the operator’s vehicles, and the condition of the infrastructure.
Heavy transport on existing lines: the assessment of bearing capacity of track-bed based on track stiffness measurements and theoretical studies

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ABSTRACT

A research project entitled "Tunga transporter på befintlig järnväg: bärighetskrav och bärighetsåtgärder" has been carried out at Trafikverket [1], aiming to assess the bearing capacity of existing lines for heavy transports in an effective way and, further, to propose necessary requirements and maintenance suggestions so as to ensure the accessibility of heavy transports. In this presentation, we only summarize the obtained results from the theoretical study part of this project.

A number of commonly used freight wagons with different characteristics in terms of axle load, speed, linear mass and bogie structure are considered in the study. Bandel 391 between Ställdalen and Frövi has been evaluated under current maintenance conditions, which is about 60 km long ballasted track with 50 E3 rail, concrete sleepers and varied substructure and track quality conditions.

The classical Zimmermann-Eisenmanns theory [2] is applied. In particular, two following improvements are achieved:

1. \(C_{zh}\), the so-called ballast coefficient, or the foundation module at contact area between sleeper and ballast, is no longer estimated just by experience, but is based on the continuous track stiffness measurements performed by the Track Recording Car IMV 100 [3].

2. \(DAF\), the so-called Dynamic Amplification Factor, is no longer determined by vaguely judging the track quality good or bad, but is associated with the parameter representing actual track geometric quality, namely, the standard deviation of longitudinal level, measured by Track Recording Car and extracted from OPTRAM.

By simulation, we have obtained the results of stresses and deflections for rail, stresses and deflections for sleeper, stresses at sleeper/ballast interface and, finally, stresses at the track-bed level, namely, 30 mm under sleeper within subgrade. Accordingly, we have performed an assessment for the bearing capacity of the whole Bandel 391 under current maintenance conditions. The simulation results are useful for identifying the sections which may potentially have problems for heavy transports and also for suggesting the required values of \(Ev2\) at the level of 30 mm under sleeper for bearing capacity.

New Concept for Higher Speed on Existing Catenary System: Auxiliary Pantograph Operation

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Abstract

The main railway lines in Sweden have been electrified since the beginning of the 20th century, and there have been many types of catenary systems developed by now. Due to the structure of the catenary, stiffness variations and wave propagation in the catenary system can cause high dynamic loads in the contact between pantograph and catenary at high operating speeds, which undermines current collecting quality, shortens the life cycle of the infrastructure and increases the maintenance cost. In order to increase the operational speed on existing catenary systems, especially on soft catenary systems, technical upgrading is usually necessary to limit the force variation within an acceptable range. According to previous studies, possible technical modifications are: tension force increase on the catenary system, catenary design with stitch wire, auxiliary wire and mid-span sag, pan-head mass reduction, and actively-controlled pantograph. However, the implementation of most of these measures does not only need large investments but also long out-of-service time. Therefore, it is desirable to explore a more practical and cost-saving method to achieve higher operational speed on existing lines.

With the help of a 3D pantograph-catenary finite element (FE) model, a parametric study on two-pantograph operation at short spacing distances is carried out. Results show that although the leading pantograph suffers from deterioration of dynamic performance, the trailing pantograph achieves a better dynamic behaviour by using a proper spacing distance between pantographs at some certain speeds. The results also show that the two positive effects still remain even with some system parameter deviations. To take advantage of the effects and to avoid the additional wear caused by poor dynamic performance on the leading pantograph, it is suggested to use the leading pantograph as an auxiliary pantograph which does not conduct any electric current. To help implementation of auxiliary pantograph operation, optimized uplift force on the auxiliary pantograph is proposed, which can not only reduce the mechanical wear caused by the auxiliary pantograph but also further improve the dynamic performance. In addition, results show that the system does not become very sensitive to small deviations of some system parameters. Meanwhile, to avoid some unfavourable working conditions and to pass through special sections, it is possible to lower or raise the auxiliary pantograph on purpose during operation to ensure safe operation.

In this way, without large modifications necessary to be made on the existing catenary system, the operational speed can be increased by 30%, and the same dynamic behavior existing at current maximum operational speed of the systems can be sustained. Therefore, this solution gives us a new option to upgrade the railway pantograph-catenary system, in which the traveling time for passengers and the infrastructure investment for railway operators can be significantly reduced. Correspondingly, the large amount of green gas emissions and the solid waste due to the system upgrading can significantly be limited.
Keywords: existing catenary system, speed increase, auxiliary pantograph, optimized uplift force, pantograph raising/lowering, system sensitivity.
Hand held apparatus for friction and wear measurements of railway tracks

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A completely new compact handheld measuring apparatus (only 2 dm long and 1 dm wide) which in an unusually simple way, in reality direct on the railroad in the field, can measure both friction and wear values for the railroad is developed. The measurements with the apparatus take into account that there are always grease residues, moisture and other deposits on the railway, which greatly affect the measurement readings. Thus more realistic data for wear, crack and maintenance simulations will be achieved. The apparatus is adjustable for all types of rail dimensions and wear levels and for different axle loads. This leads to new opportunities for significantly better and more realistic input to simulation programs that researchers can use to predict the need for maintenance of rails and wheels, as well as to simulate safety as regards to braking distances. The invention has resulted in two patent applications.
The influence of corrugation on tangential forces and rolling contact fatigue

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Rail corrugation, and in particular short-pitch rail corrugation, is a well-known phenomenon commonly related to high-speed operations. The undulations of the rail surface will generate noise and cause high contact forces in the wheel–rail interface. If conditions are sufficiently severe, the latter phenomenon may result in subsurface initiated rolling contact fatigue in wheels (and likely also in rails). This issue has been investigated previously; see e.g. [1–3].

Subsurface initiated rolling contact fatigue relates to high contact pressure in the contact patch between wheel and rail. A more common phenomenon is surface initiated rolling contact fatigue, which is closely related to the interfacial shear stress between wheel and rail. In rails this type of damage is manifested in the form of headchecks and squats/studs. It has been shown [4] that squats may be generated in the presence of corrugation (as well as initiating corrugation). This poses the question as to how rail corrugation affects the spectrum of frictional stresses between wheel and rail.

That there is an effect has been established in previous studies. However, this effect has not been quantified in detail, which this study sets out to investigate. In particular, the focus is on how frictional stress magnitudes are affected by parameters such as speed, tractive efforts and roughness spectra. To this end, dynamic simulations of the wheel–rail interaction are carried out. Tractive efforts of varying magnitudes, as well as (measured and synthetic) corrugation spectra are employed. Due to the short wavelength of the corrugation and high speeds, these simulations need to account for the high-frequency content of the induced force spectrum. In-house codes calibrated and validated against full-scale measurements on high-speed lines are employed, see e.g. [1, 5].

Results are interpreted in terms of force and rolling contact fatigue impact spectra. In particular, a shakedown analysis approach is adopted and contact stresses are interpreted in terms of the $FI_{surf}$ rolling contact fatigue index. A high magnitude of this index corresponds to a high probability of surface initiated rolling contact fatigue. The study will establish under which conditions this will occur, and its root causes (i.e. poor contact geometry and/or high tractive forces).

The results of the study are believed to be of use in establishing maintenance practices on high-speed lines. In particular, they will provide means to establish grinding practices under different operational conditions. This is, in particular, the case if the analyses are coupled with predictions of generated noise levels, cf. [3].


The Swedish procurement strategy – a literature review

Jens Modig, LTU

The Swedish Transport Administration (Trafikverket, TRV) is changing its procedures for procurement of railway maintenance. The intent is to stimulate contractors to innovate and develop their processes for how to perform maintenance work. The contracts differ and changes in government policies during contracts make contract comparison harder. A literature review has been conducted to understand the conditions in the Swedish infrastructure sector, to understand the change in procurement strategy and how to encourage contractors to innovate. The review covers both internal and external documents from TRV and articles related to the subject. What procurement strategies are there? How is maintenance evaluated? How does it affect the innovation opportunities for entrepreneurs?

The literature review is a part of a research project with an overall goal to develop a model to guide the selection of appropriate type of procurement strategy, contract and control of maintenance for a more sustainable railway system.
Wheel life prediction model considering wear and RCF: LKAB Iron-Ore Loco

The Swedish iron-ore company LKAB uses Bombardier Co-Co locomotives with 30 tones axle load to transport pellets from the mines in Kiruna and Malmberget to the ports in Luleå and Narvik. Each loco unit consists of two identical Co-Co locomotives coupled back to back permanently. There are 68 wagons connected to each loco unit and in the laden condition the total weight carried by the loco is more than 8'000 tons. The simulation model of the loco is built at Bombardier. The average running distance between two consecutive wheel turnings is around 50'000 km and it is mostly due to rolling contact fatigue (RCF).

In order to study the effect of various parameters such as braking and acceleration on the wheels life an RCF prediction model is developed. To predict the wheel life with respect to RCF, the wear of the wheel profile is also taken into consideration. For RCF calculation the concept of the shakedown diagram and the Palmgreen-Miner rule together with laboratory test results are used. The tests are carried out at Chalmers University of Technology. The uniform wear prediction method is developed at KTH using Archard wear calculation theory.

The procedure contains a number of so-called wear steps with a set of time-domain simulations reflecting the actual rail network, i.e. design geometry, rail profiles, track irregularities, coefficient of friction and the gradient of the iron-ore line.

The results are compared with the available measured data and a good agreement is achieved.

The loco is equipped with both pneumatically actuated tread brakes and ED-braking. However, pneumatic braking is rarely performed and most of the time (more than 95%) the Ed-braking system is used. To calculate the braking and traction effects a force is applied at the loco rare at the buffer height. This force is calculated based on the topography of the line, the running resistance from curving, aerodynamics and mechanical resistance for each simulation case. Then, a PID control system in the model keeps the speed constant by applying a torque on the loco wheels. The maximum braking force that can be applied by the ED-brakes is 250 kN for a loco unit and the rest is taken care of by the wagons shoe brakes.

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Title of Paper: Increased Axle Load to 32.5 tonnes – what Operational and Maintenance effects will it have for the Rolling Stock?

Authors: Thomas Nordmark

Company of Affiliation: Luleå Technical University & LKAB

Abstract:

Abstract: The ore line (Malmbanan) is a 500 km long track section located in northern Sweden and has been in operation since 1903. It is mainly used to transport iron ore and pellets from the mines in Kiruna and Malmberget to Narvik harbour (Norway) in the northwest and Luleå harbour (Sweden) in the southeast. The track section, on the Swedish side, is owned by the Swedish government and managed by the Swedish Transport Administration (Trafikverket) and on the Norwegian side by Jernbaneverket, while the locos and ore cars are owned and managed by the freight operator LKAB.

LKAB has in the last 15 years continuously developed the transport system for hauling the iron ore. Increasing the axle load from 25 to 30 tonnes, increasing the train length from 500 meter to 750 meter (52 to 68 ore cars), reducing the cycle time from 15 hours to 12, invested in new IORE-locomotives (17 units) and 1.130 new ore cars. The recent development is to increase the train weight to 9.200 tonnes through an increase in axle load to 32.5 tonnes. This development started September 1:th 2015 with a dedicated test train running from the mine in Malmberget to Luleå once a day.

A research program is connected to this test at Luleå Technical University and the department of Operation & Maintenance. This program is focused on the effects for the maintenance need and effects for the rolling stock when the axle load is increased. The research program will be finished in August 2018.

The extended abstract will presents the result in general so far regarding operational and maintenance effect like axle load variations, lateral forces, wheel damages and other results from the follow up of the test train.

Keywords: LKAB, Malmbanan, Heavy Haul Railway, wheel life, wheel maintenance practice, maintenance limits
A case study on Railway Infrastructure Robustness for Switches and Crossings

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According to the European program Horizon 2020, multifaceted challenges in transport infrastructure include 1) making infrastructure more resilient to keep pace with the increasing mobility needs; 2) reducing the impact of infrastructure on the environment; and 3) dealing with declining resources to maintain and upgrade transport infrastructure. New design and maintenance approaches must be developed to handle these issues, as current methods are inadequate.

In maintenance practices of railway infrastructure, most attention has been placed on RAMS (Reliability, Availability, Maintainability and Safety) study to meet asset safety and availability requirements. In Sweden, a popular development of the concept is RAM4S which incorporates supportability, sustainability, and security. However, the reality is more complex than these concepts suggest; various natural or operational uncertainties can cause “unfavourable” conditions requiring a quite different approach.

Resilience studies can improve the ability of an infrastructure to withstand disturbances caused by uncertainties. To this point, most studies have considered extreme events, including natural events, like earthquakes or floods, and man-made events, like deliberate attacks on infrastructures. However, both naturally caused and operationally caused unfavourable conditions which do not belong to extreme events need to be studied as well. This represents a significant gap in the research.

Robustness as a part of resilience has attracted much attention in recent years as it may be able to sufficiently consider those unfavourable conditions. In railway systems, however, robustness studies have mainly been aimed at timetable management to handle delays (including secondary delays) within the system. Yet according to statistics on total delays for the year 2015, from the follow-up system of the Swedish Transport administration (Trafikverket), LUPP, more than 30% of the root causes of delays are due to non-robust infrastructures.

A framework for evaluating and improving the robustness of railway infrastructure is used to evaluate the robustness of switches & crossings in winter conditions.

With the mounting financial and legislative pressures on the railway industry, monitoring and optimizing energy consumption are becoming crucial. According to research findings, energy accounts, on average, for around 15% of the operational
costs of infrastructure owners. Effective snow and ice protection has a significant influence on the successful operation of railway switches and crossings (S&C) on the Iron Ore Line (Malmbanan, Sweden). One strategy is to remove snow and ice with electrical heating. However, the task consumes a great deal of energy. According to the Swedish Transport Administration, the total energy consumption for the 6 800 S&C equipped with electrical heating is about 200 GWh/year, at costs of approximately 15 M€/year.

This paper designs a hierarchical modeling framework for energy consumption monitoring of snow and ice protection for S&Cs. The purpose is to measure and optimize energy efficiency to support maintenance strategies’ review and optimization (MSRO). The proposed framework is developed both qualitatively and quantitatively. For the former, parameters influencing snow and ice removal capabilities of S&C are identified using investigation and interviews. For the latter, the developed model takes into account how the protection strategy is actually used by considering hourly provided data on energy consumption, temperature, precipitation, wind conditions, track workload, and failure reports. In addition, design of experiments (DOE) technology is used to determine how each critical factor (energy consumption, arctic conditions, etc.) affects the performance of different S&C snow and ice protection strategies.

The data in the case study have been collected from the Swedish Transport Administration and are used to demonstrate how the proposed framework can be applied. The results of this study will specifically influence the strategy of snow and ice protection on S&Cs at the Swedish Railway Administration, but the framework can be used for other railway infrastructures.
Estimation of wheel-rail friction at vehicle certification measurements

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Abstract

In certification of new rail vehicles with respect to running characteristics a wide variety of operating conditions needs to be considered. Behaviour on straight and curved tracks, including twisted tracks are all of great importance at various speeds. However, the wheel-rail friction should always be high corresponding to dry conditions. It means that the tests have to be carried out during dry weather conditions and unlubricated rails. But measuring the friction at test conditions is a great challenge.

Therefore, in a recent work (Petrov et al.), an algorithm was proposed for the continuous estimation of wheel-rail friction along both rails. The algorithm is based on wheel-rail forces in all three directions (Y, Q, X) for both wheels in a wheelset, lateral contact position on its wheels and wheelset angle of attack. The algorithm was evaluated with a fictional vehicle with vehicle-track dynamics simulations on various tracks (straitgh and $R=1000$ m curve) and track irregularities. It seems promising, but evaluation based on track tests was not possible at the time.

In cooperation with SNC Lavalin (formerly Interfleet), an opportunity arised to get the required data from on-track tests. In this way, all nine quantities above were measured during test runs of a new vehicle, so the algorithm could be evaluated under realistic conditions. The tests in tight curves of radius 150 m are used in the present work for this purpose. The measured data and the algorithm were processed in a Matlab program to get the friction estimate. Apart from the friction, the creepages and spin are also monitored to see what influence they have on the results. Ultimately, more objective friction estimates and simpler on-track tests should be achieved.

The presentation will show possibilities and limitations of the algorithm, as well as some statistical options of postprocessing the friction signal.
Passenger train delays in southern Sweden

Carl-William Palmqvist, Teknik och Samhälle, LTH

Abstract

The aim of this paper is to study how selected variables influence delays in train traffic. Data has been collected on train movements, timetables, weather and capacity utilization on a highly utilized single track railway line in southern Sweden during 2014.

Based on this dataset, we have analysed how different factors affect delays in passenger traffic. We measure delays in a novel way, as deviations from the scheduled duration for each line section and station stop, not as deviations from a published or operational timetable, and this allows us to identify when and where the delays first occur. Average delays were much larger at station stops.

The most significant factor affecting delays was the scheduled duration time at station stops, and the existence of margins on line sections. If trains arrive to a line section or station stop slightly delayed they speed up the activity, otherwise they are typically delayed.

The influence of weather was less significant and somewhat contradictory: snow and cold temperatures increase delays on line sections but reduce them at station stops, while precipitation made no difference.

Capacity utilization seems to have a negative correlation with delays, but we have too little variation in the levels to be confident.

All studied variables, except for precipitation, have impacts that are statistically significant to a very high degree of confidence, using both t-tests and regression analysis.

The results of this study have important practical implications for timetable construction, for instance we estimate that a reallocation of scheduled time at stations could reduce delays by as much as 80%.
Working together to find better solutions: Methods facilitating collaboration in the context of a deregulated railway market

Anna Malou Petersson, LTU

The OptiKrea project, run by Luleå Railway Research Center at Luleå University of Technology, was initiated in 2012 with the intention of promoting the technical development of railway products, especially from the point of view of maintenance and life cycle cost, by introducing new working methods. The deregulation of the Swedish railway has resulted in different market actors managing, supplying, maintaining, utilizing and researching the railway. The idea behind the OptiKrea project was that, by integrating the different perspectives on and knowledge about railway products and maintenance processes that the different actors possess, better solutions would be found. The goal of the project was to develop working methods for the conceptual design phase, including ideation and decision support methods, which would facilitate innovation through collaboration, would be tailor-made for the railway sector and could be used in the future. The turnout was chosen as the case object for the scope of the project, since the turnout is a vital part of the railway infrastructure and a failure of a turnout, especially in a critical location, can cause significant delays and societal costs. At the heart of the project is the so-called “creative team”, which consists of representatives from each collaborating actor. The team is cross-functional in the sense that it represents the different functions that are important when developing a turnout, i.e. research, design, manufacturing, management, maintenance, and disposal. The project has developed collaborative methods for problem mapping, requirement specification, idea generation and decision support. The methods have been successfully tested in the creative team and the ideation method has been validated in the In2Rail and UPPSAMT projects. The Swedish infrastructure manager (Trafikverket) is currently looking into how the methods can be implanted in their routines. This presentation will cover a description of the project, an overview of results and a discussion on collaboration on the Swedish railway market.
Dynamics of SCA Logistics Wagons and its Influence on Wheel Damage

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Abstract

Hector Rail AB is a Swedish line haul provider for the European Rail Transport Market. They use their own locomotives and rent the wagons. On one line, Hector Rail transports large cylinder-shaped paper rolls of different sizes to Skövde, and compressed return paper shaped as cubes back to Holmsund, where the customer is SCA Logistics. The wheels of these wagons are experiencing surface initiated rolling contact fatigue, RCF. In a collaboration with KTH Royal Institute of Technology, a project has been carried out, where the main purpose was to study the risk of development of RCF cracks on the wheels of these vehicles with Y25 running gear. The dynamic analysis was done for three different load cases: Two different paper roll cases and one return paper case. In addition to this, three different wheel-rail friction coefficients have been studied. With measured track data, the analysis shows for what curves, and in what track sections RCF will appear.

This presentation focuses on the effects of the different load cases and friction coefficients, and where it is expected to experience RCF, as well as some suggestions of improvements and what can be done in the future.
Kinematic Principles in Switches & Crossings

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The Switch & Crossing (S&C) is a vital component in railway networks as it provides flexibility to traffic operation by allowing trains to switch between tracks. The flexibility comes at a cost however as switch actuation and customized rail and bearer solutions increase complexity and expenses. Therefore S&C are often described as “hungry assets” due to their high maintenance costs compared to standard track.

The problem with the customized rails is that their associated wheel transitions – from stock rail to switch rail and wing rail to crossing nose – cause higher wheel-rail contact forces and therefore higher rail degradation rates compared to regular track. The aim of this presentation is to describe and analyze these discontinuities in order to identify potential areas for improvements in S&C design and maintenance.

It is described how the composite rail profile consisting of stock rail and switch rail cause rolling radius deficiency in the switch. This deficiency leads to poor wheelset steering and high lateral forces for traffic in the diverging route. The size of the residual switch rail opening – the remaining gap between stock rail and switch rail after closing – that can be allowed while avoiding interference contact between passing wheels and the switch rail tip is also discussed.

It is shown how the dip in vertical position for a wheel that passes over a crossing is a necessary evil. Without this dip – which causes an undesired impact force – a standard fixed crossing would not be able to accommodate wheel profiles of different shapes. In Figure 1 it is illustrated how wheel profiles of different shapes make the transition from wing rail to crossing nose at different longitudinal positions in the crossing.

Figure 1. Transition from wing rail to crossing nose for two different wheel profiles at two different locations in a crossing.
A Novel Flowchart for Studying Active Suspension Failures in Rail Vehicles

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With increased application of active suspension in rail vehicles, the need for a systematic procedure for checking safety of the vehicle in case of an active suspension failure is getting more important. A failure in an active suspension may not only put safety at risk but can also affect the acceptance of this technology by rail vehicle operators and authorities. Therefore assuring safety in all possible failure scenarios of active suspension seems essential.

To the knowledge of the authors there are very few studies on failures of active suspension in rail vehicles and there is not any proposed systematic method to perform these types of studies. The aim of this study has been to use the available knowledge for building a general framework, which will enable experts to locate all possible failure scenarios of the active suspension in study. Different active suspension technologies like tilting, active lateral/vertical suspension, hold off device, active wheelset steering etc. may be studied through this framework. The framework is presented in form of a flowchart. The back bone of the flowchart is based on existing knowledge from failure mode and effects analysis (FMEA) and fault tree analysis (FTA) and the relevant sections from EN14363 standard on vehicle running safety.

FMEA and FTA are two widely used methods in reliability engineering analysis which are commonly used in different industries like aeronautics and automotive industries. These tools will be used in this study for providing a comprehensive and rational engineering framework for covering different active suspension failure scenarios.

To judge if a failure scenario is safe or not, there is a need for a set of vehicle dynamics performance criteria. Such criteria can be found in EN14363 standard. The criteria are designed to ensure safe running during all possible conditions.

Finding the correct failure modes can be a challenge. Therefore, this study suggests six different failure modes which can be applied to different active suspension systems and they are addressed as being conservative and inclusive. They are considered conservative as some of them are very unlikely to happen and inclusive since they cover almost any type of force application. Introduction of these failure modes can contribute to a much faster failure analysis.

In the rest of the study a case study is considered where it is practically shown how the flowchart should be applied and interpreted. The case study addresses how the number of simulations can be reduced by vehicle dynamics experts. Furthermore, four failure examples are provided to explore all possible routs of the flowchart to the ‘End’ point.

This study provides a systematic method for studying active suspension failures in rail vehicles. Furthermore, it is shown how the method should be implemented.
Structural challenges with railway catenary systems

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The sole purpose of railway catenary systems are to ensure transfer of electrical power to passing trains. The physical contact between the train and the catenary that ensures this is between the collector strips at the pantograph and the contact wire. This interaction is a coupled nonlinear dynamic system that renders dynamic behaviour of two structural systems, the pantograph and the catenary, as well as wear on the contact wire and the collector strips. The most important structural challenges regarding this contact is to ensure a desirable movement of the catenary as trains passes, and to have control on the wear of the contact wire and the collector strips. This is especially true for higher speeds, both for existing sections where the speed has been increased and for newly built sections.

The present structural challenges can be divided into different types of loading, increased speeds on existing catenary sections original designed for low speeds and new catenary systems designed for higher speeds. Both types will experience dynamic movement and wear. The majority of the Norwegian rail network has catenaries designed for quite low speeds, which more or less mean that they were designed for static forces. It is very important to maintain control of the amount of wear and the movement due to increased train speeds to ensure a stable and predictable electric transfer and wear. Historically the Norwegian systems have exhibited low wear, and have been used for up to 50 years before they have been too worn. New catenary systems designed for higher speeds are expected to have a better defined dynamic movement, but will, because of the high speed, also experience increased dynamic forces and thus higher wear compared with low speed lines.

In general, increased train speeds leads to higher forces, and probably larger variations and more arching, and more wear. To lengthen the life span of these systems it is therefore extremely important to know about these effects, and to identify possible problem points. Some high local wear has been experienced and that lead to a significant decrease of service life. It is expected that the increase of local effects will be more prominent than a general increase in wear. To be able to study these effects in detail one need numerical models of good accuracy. To ensure that a model is of high accuracy is important to validate the numerical models against field measurements.

Possible solutions for these challenges are to ensure that the vertical stiffness variation of the catenary systems is small, and that the vertical motion of the pantograph is equally small. That is, it is important to revise the use of variation in span lengths within one catenary section, more variation in tension forces, or for existing sections, local re-tensioning.
Digital Twin: Enabling PHM at Industrial Scale

Keynote by Abhinav Saxena

Senior Researcher in Machine Learning lab at General Electric Global Research Center.

PHM technology has always been a key driver of business value for industrial assets, however with the invent of Industrial Internet the possibilities seem endless on how these assets can be further optimized, maintained, and improved for productivity. Powered by GE’s industrial internet platform Predix, Digital Twin is a game changer on how assets are monitored, managed, and maintained at scale. Digital twin platform offers a one stop platform to build data or physics models, test and validate before deploying them. This talk will highlight key aspects of Digital Twin and how through connectivity and cloud-based computing it is enabling per asset models to track individual assets' health and life. Consequently, PHM algorithms are being deployed at scale, where millions of models are being built, deployed, tracked, and managed over the lifetime of assets. Examples from various domains including transportation will be presented to give a flavor of different PHM analytics and the business outcomes they are driving.
Rail grinding has become an essential part of track maintenance. Besides corrective work to remove corrugation and surface damage, a growing number of infrastructure managers have started to program grinding as preventive measure in a cyclic regime in order to keep rails in good shape throughout their whole service life and decrease the life cycle cost (LLC) of the rails as well as the whole track. The intention is that the development of any severe surface defects can be effectively avoided. Ideally an optimal maintenance strategy would start with new, initially ground rails.

Very often rail life is considerably long and - rather than waiting until rails have to be changed - corrective grinding work is planned in order to assure optimal surface conditions at a certain moment. Occasionally severe defects may have already developed and require heavy rectification activities before preventative maintenance work can start.

On the other hand, when cyclic preventative grinding is the chosen maintenance strategy, originally planned work cannot always be executed according to plan and often track and traffic conditions change in the course of time. Adaptations of the once chosen maintenance plan may be delayed or not in line with the actual situation. Apparently there is not only one solution which would fit all rail surface problems, in particular when rolling contact fatigue is the main reason for rail maintenance.

The intended presentation discusses the reasons for varying defect development and the need to react in a flexible way. Also consequences regarding remaining or only partly removed defects will be addressed. Examples from practice – some of them being rather extreme – are presented and show the wide range of applying the grinding technology in the most appropriate way in order to avoid unexpected negative side effects. The presentation ends with some reasoning about the proper grinding strategy and its influence on the LCC.
Traffic Management System (TMS) for the Future - Ole Torp Sejersen

Foreword
I’ve been working more than 20 years for the Railway and my current rank at two Danish private railways was Traffic Chief Superintendent. I’ve worked in Control Centres and signal boxes and also in the timetable department including app. 20 years for several manufacturers of railway technologies - Bombardier - Siemens - Cactus Uniview.

This document describes a research and optimising study of how to improve current Traffic Management Systems for conventional lines firstly for single track lines and secondly for double track lines. It contains proposals for improved Human Machine Interfaces (HMI) and enhanced functionalities.

The main issue is to provide the operator with an upgraded HMI, which provides all the information required for supervision and manual operation and minimisation of the use of several menus, thus allowing the operator time to respond more quickly and efficient.

The new functionalities will also allow more efficient planning and operational control.

New approach
Based on my previous experiences from working in a Control Centre, I am convinced that the Train Graph (Time/Distance diagram) with modifications and upgraded functionalities will be able to provide the operator with all the necessary and required information allowing full control of all traffic operations including irregularities.

In modern TMS systems, the operator only has to monitor the automatic train operations

Challenge
When using input from track circuits and axle counters for a Train Graph the train’s movement will be stepwise and not smooth

In order to make a static train graph operational and thus better for supervision and control of traffic, it is essential to abandoned train position based on track circuits and axle counters.

They detect the train’s position at the beginning of the covered area - that can be several kilometres long - and thus not suited for updating a Train Graph allowing an operator to monitor the traffic and make decisions based on its information.

Our solution
For a safe and never-ending input from the trains’ it’s necessary to use one of the following technologies:

- GPS-data
- Data from the Radio Block Centre

These data will allow the train graph to show the exact position of the trains and update the trains’ line on the Train Graph allowing the operator to pinpoint the exact position of each train in the covered area and allowing the prediction of delays, irregularities and other disruptions.

It will also be able to show each category of trains with different colours and thickness of the train’s line.

This will also indicate indirectly how many train-sets are in operation at a specific time or during the entire day allowing the operator to know how many engineers he needs to replace in case of a disruption. On the Train Graph, you can show the track layout of each station and the entire line. Also at each station, you can show all the corresponding trains and connections. The colour of the train’s line could show the present state of the train:
SIMULATION OF MATERIAL DEGRADATION IN TRACK SWITCHES

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In railway industry, high maintenance costs are related to track switches and crossings (S&C), often because of the need to repair or replace rail components. The costs can be reduced by choosing an appropriate material for the components of the S&C and knowing when to perform maintenance.

A simulation methodology, integrating several cross-disciplinary numerical tools, for the prediction of rail profile degradation in track switches has been suggested in Johansson et al. [1]. The methodology consists of the following steps: 1) Vehicle dynamics simulation (GENSYS or SIMPACK) in order to predict wheel-rail contact forces, creepages and contact positions. 2) Contact simulations (Abaqus), using a user subroutine UMAT with an elasto-plastic model [2], to determine realistic contact patches and stresses in the material. 3) Simulation of damage evolution, accounting for the plastic deformation and wear. In step 2, in order to reduce the computational time, local 3D models of the wheel-rail contact are created based on the assumption that the radii of curvature of both wheel and rail are constant in the vicinity of the contact point.

The aim of the current work is to improve and extend the simulation methodology in terms of robustness and computational efficiency. For instance, the finite element simulations in step 2 can be replaced by simplified metamodels using Response Surface Methodology [3]. Details concerning the implementation and performance of such a metamodel will be presented.

References


Elasticity in track gives increased availability.

Abstract

Under ballast mats and under sleeper pads has been used in track superstructures for many years in order to isolate vibrations and structure borne noise.

But by introducing elastic elements in the track you also gain other advantages, such as; increased track geometry stability and ballast protection which leads to reduced maintenance and lengthens the service life of the track and in the end an increased availability to the track.

The presentation focus on how sleeper pads and ballast mats works and what technical demands you need to take into account when introducing these elements.

Time: 40 minutes including questions (30+10)

Speaker:
Magnus Sköld. M.Sc. / Sales Manager, Vibration Technology Christian Berner AS, Norway
A significant part of railway track maintenance cost is related to track geometry maintenance activities. Modeling the track geometry degradation is an essential prerequisite to plan maintenance activities in advance to keep the track geometry condition in an acceptable level and to minimize total maintenance cost. In this regard, track geometry degradation and recovery should be properly modeled to have an accurate prediction of track geometry condition. In addition to the degradation cumulated gradually, the geometry degradation path may suffer a sudden change. In this study, a probabilistic model for track geometry degradation with possible change points is developed. The track geometry degradation in a maintenance cycle is modeled using a linear model with random coefficients. It is found that model parameters, i.e. initial degradation level after tamping and degradation rate are random variables following lognormal distribution. When a change occurs in the degradation process, a two phase linear regression model will be used. The root causes for the changes in degradation parameters are not completely obvious. It is found that the bumps (peak) in geometry data measured in every 25 cm are corresponding to sudden changes in degradation parameters. A possible reason for the changes in degradation parameters can be replacing a few numbers of sleepers in track section. In addition, installation or replacement of steel drums may also cause a change in track geometry condition. A change point detection method based on F test framework is applied to identify these change points. Probabilistic models based on real data are used to model the position and magnitude of the change points. In addition, a probabilistic recovery model is proposed to estimate recovery values after tamping interventions. In order to characterize the recovery effect of tamping on track geometry condition, three models, i.e., standard linear model with constant variance, linear model with increasing variance, and a Weibull model are applied and compared using Schwarz’s Bayesian Information Criterion. The results of the comparison based on SBC confirm that the proposed Weibull model can properly use for estimation of recovery value after partial and complete tamping. In addition, in this study it is shown that the neighbor track sections tend to have similar degradation parameters and the spatial correlation between neighbor track sections should be addressed. The reason for this behavior is that the neighbor track sections have similar structural and operational conditions. Therefore, the close sections tend to show similar degradation behavior. The data for the Main Western Line in Sweden is used to estimate the model parameters. The Main Western Line in Sweden (Västra Stambanan) is the main railway line between Stockholm and Gothenburg. It is a double-track, electrified and remotely blocked line, used by both passenger and freight trains. The maximum speed of trains on the Main Western Line is around 200 km/h. On this selected main line, line section 414 between Järna and Katrineholm Central Station is used for the case study.
Nytt EU-direktiv med krav på järnvägsfordon och andra delsystem för järnväg

Ett gemensamt signalsystem i hela EU, järnvägsfordon som är godkända för trafik i hela EU+. Det är grunden för EU:s vision om ett gemensamt järnvägssystem. Ett nytt EU-direktiv och nya tekniska specifikationer för driftskompabilitet (TSD) anger väsentliga tekniska krav för järnvägsfordon och andra delsystem för järnväg.

EU beslutar i sommar om ett nytt direktiv för driftskompatibilitet i EUs järnvägssystem 2016/xx/EU. Målet är att uppnå ett gemensamt järnvägssystem utan tekniska och administrativa barriärer genom att:

- Ett gemensamt signalsystem (ERTMS) med tågskyddssystem och tågradio, utformat enligt EU:s förordning om TSD Trafikstyrning och signalering
- Järnvägsfordon som är godkända för trafik i hela EU och som uppfyller väsentliga tekniska krav enligt EU förordningar om TSD:er
- Järnvägsinfrastruktur inklusive energisystem som uppfyller väsentliga tekniska krav enligt EU förordningar om TSD:er


När järnvägsbyrån har en ansökan med en teknisk fil och Nobo-intyg från de anmälda och utsedda organen kan de godkänna fordonstypen för ett område för användning. När det gäller infrastruktur är det även i fortsättningen Transportstyrelsen som godkänner nya och ombyggda anläggningar i Sverige. De nationella reglerna täcker i princip endast krav som inte täcks av TSD avseende fordonens kompatibilitet med den svenska infrastrukturen inkl. vinterförhållanden.

De tekniska kraven i TSD:erna för fordon är ”state of the art” för tillverkarna i Europa. De hänvisar i stor utsträckning till EN-standarder avseende t.ex. gångdynamik, fordsprofiler och strålkastare. TSD Trafikstyrning och signalering anger att tågskyddssystemet ska vara av typ ERTMS på alla nya fordon. EU kräver också att medlemsstaterna inför ERTMS på marken.
ePilot119: Uppföljning av nulägeanalysen (delprojekt 036)

Christer Stenström
Avd. för drift, underhåll och akustik
Luleå tekniska universitet

Abstrakt

Recent advances in numerical prediction of rail corrugation growth

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Rail corrugation growth (i.e. periodic irregularities with distinct wavelengths), and it’s associated pronounced dynamic loading that leads to increased generation of noise and vibrations, constitutes a severe problem for many railways networks worldwide. The understanding of its cause is still not adequate to allow effective control measures to be developed. Although a lot of knowledge regarding the mechanisms of rail roughness has been obtained, rail roughness, particularly the short-pitch corrugation and the combined types of corrugations, still remains a puzzle for researchers and infrastructure managers.

The process of rail corrugation growth is a combination of transient coupling dynamics of the vehicle-track interaction and the long-term effect of cyclic loading. As a result, numerical approaches are a powerful and practical way to look into the mechanisms, the initiation, the development and the steady-state of rail corrugation, and to investigate the effect of the track, the vehicle design, and the loading condition on the rail corrugation growth.

An overview of a state-of-art and recent advances in the numerical prediction of rail corrugation growth, such as considering both plastic deformation and wear of the running surface of the rail, including modelling full flexible wheelsets, use of advanced contact models, efficient nonlinear time domain analysis, and broad-band rail roughness prediction, is surveyed. Additionally, the limitations, challenges, and knowledge gaps in the surveyed researches and the possibility for further improvement are discussed. This study gives a guidance on future directions of the research on rail corrugation growth.
Numerical optimisation of railway crossing designs

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Railway crossings are important operational elements in railway infrastructures. The discontinuity in the rail geometry at the crossings results in high impact loads at crossing noses. These dynamic forces can cause severe damage to the crossings. The goal of the research is to develop a methodology that optimises the vehicle-track interaction at railway crossings by tuning the crossing design. This will reduce damage to the crossings and finally increase the availability of the railway network.

Optimisations in the traditional railway system design is carried out in a primitive way by modifying the design parameters, mostly based on the designer’s experience, and repeated numerical analyses.

In the methodology developed here, the crossing design improvement is performed systematically by using numerical optimisation techniques to solve problems with multiple criteria, design variables, and constraints. The optimisation focuses on the reduction of damage to crossing, especially that by rolling contact fatigue (RCF), from impact forces. In order to achieve this reduction, the geometry of the crossing and the vertical elasticity of the crossing are optimised. The assessment of the crossing design is based on dynamic analyses of the train-track behaviour using the multibody simulation method and the finite element method, which in the design improvement process were coupled with the optimisation technique.

Moreover, the developed methodology is extended to solve optimisation problems with parametric uncertainties, such as tolerance of design parameters. For this purpose, the robust optimisation method is used, which results in robust optimum solutions. This study provides guidance for both the production of new crossings and the maintenance of existing crossings.
EN 14363:2016 – a new and feasible way of homologating vehicles from a running dynamics point of view

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Homologating new vehicles, rebuilt vehicles or vehicles used in a new way has often been a very long and costly process. Furthermore, due to requirements on testing conditions it has been difficult, sometimes impossible, to run tests in one country for acceptance in others. To address these concerns CEN has given an expert group the assignment to revise the standard governing this process (EN 14363) with the instructions:
- Not to make acceptance more costly or time consuming
- Not introducing new functional requirements – the railways of today are considered safe
- Facilitate the possibility of testing in one country for a European acceptance
- If possible, simplify the assessment procedure with a maintained level of safety

The author of the paper was the leader of the group writing the new EN 14363 (CEN TC256/WG10/SG8). The work started back in the spring of 2011 and the new standard was produced during the spring of 2016.

The paper will describe the major changes that have been introduced but also:
- The background of the change, why was it done
- The discussions within the group, why it was done the way it was
- Options discussed that were either abandoned or postponed for future revisions

The major modifications include:
- The possibility of using computer simulations (virtual homologation), allowing the process to be made at a lower cost on shorter time while at the same time putting requirements on the model validation.
- A new way of analysing data, in particular taking testing conditions into account in a new way. This was done to extend the possibility of exporting test results from one country to a European acceptance (TSI acceptance).
- A new way of looking upon fault modes, facilitating addressing relevant fault modes instead of pre-defined ones.
- Introducing track loading assessment quantities believed to be more relevant than earlier ones.
- Handling of track geometric quality as well as wheel/rail geometric contact conditions.

The presentation will also discuss how it is believed that the revised standard will have an impact on the European acceptance process as well as a look into the future – what is expected to come in the next revision.
High-dimensional data streams are becoming increasingly ubiquitous in industrial systems. Efficient detection of system faults from these data can ensure the reliability and safety of the system. The difficulties brought about by high dimensionality and data streams are mainly the “curse of dimensionality” and concept drifting, and one current challenge is to simultaneously address them. To this purpose, this paper presents an approach to fault detection from non-stationary high-dimensional data streams. An Angle-based Subspace Anomaly Detection (ABSAD) approach is proposed to detect low-dimensional subspace faults from high-dimensional datasets. Specifically, it selects fault-relevant subspaces by evaluating vectorial angles and computes the local outlier-ness of an object in its subspace projection. Based on the sliding window strategy, the approach is further extended to an online mode that can continuously monitor system states. To validate the proposed algorithm, we compared it with the Local Outlier Factor (LOF)-based approaches on artificial datasets and found the algorithm displayed superior accuracy. The results of the experiment demonstrated the efficacy of the proposed algorithm. They also indicated that the algorithm has the ability to discriminate low-dimensional subspace faults from normal samples in high-dimensional spaces and can be adaptive to the time-varying behavior of the monitored system. The online subspace learning algorithm for fault detection would be the main contribution of this paper.