Global level assessments of track geometry quality along the Western Main Line in Sweden

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Introduction

This work is one of the on-going research activities within the collaboration project "A systematic approach to improve passenger ride comfort" between the infrastructure manager Trafikverket and operators SJ AB and A-Train AB, together with external partners, aiming to improve handling of bad ride comfort as well as other track-vehicle interaction issues [1]. By use of the standard approach in EN 13848-6 **Error! Reference source not found.**, global level assessments of track geometry qualities for the whole Swedish Western Main Line as well as for all its track parts (Bandel in Swedish) are carried out. The obtained results are valuable for long-term network management and strategic decisions, e. g. the SJ250-project, in which SJ is planning to operate long-distance intercity routes and cross-border services at a maximum speed of 250 km/h on existing lines.

Results

Figure 1 presents the cumulative frequency distributions (cfd) of the standard deviations (std) of Longitudinal Level (LL) and Alignment (AL) for the years 2022 and 2023. When compared to European reference results [2], the track geometry qualities along the Western Main Line are good for the current speed class of 160 km/h < V <= 230 km/h. However, to meet the requirements for vehicle speeds exceeding 230 km/h, significant improvements are required, particularly regarding lateral track geometry quality.

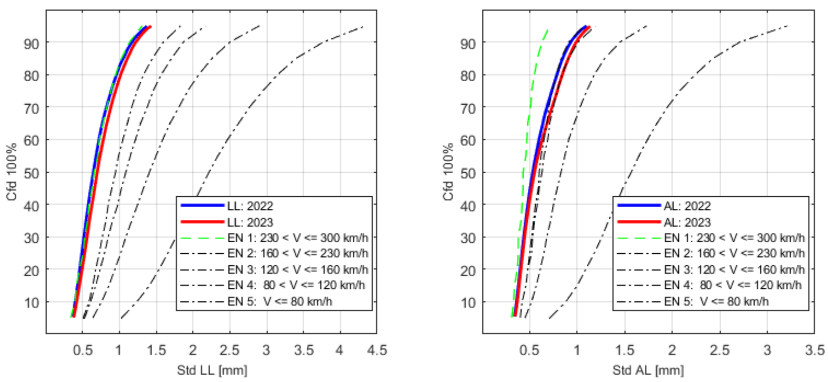

Figure 1. Track geometry qualities along the Western Main Line: stdLL and stdAL

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Assessing Finnish track health through in-service train-based track condition monitoring

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Introduction (heading in 12 pt Calibri bold)

Embracing a paradigm shift in rail infrastructure management, Finland has embarked on a pioneering pilot project to assess the health of it's track infrastructure. This initiative leverages the operational prowess of commercial traffic's traction equipment to provide continuous vibration measurements by capturing the vibration response from the wheels as they traverse the track. This allows for the daily acquisition of critical data on the whole railway network to predict the health of the track infrastructure thereby minimising the risk of missing significant changes or emerging issues. To date over 1,084,000 kilometres of diverse railway sections have been monitored with the identification of several defects. Notably, these detections were not captured by the measurement train as they had not yet surpassed the predetermined warning or alarm thresholds.

Analysis

A railway locomotive bogie is instrumented with accelerometers which monitor track condition. Time-frequency analysis of axlebox bearing acceleration measurement is carried out for selected track defect cases. In addition, the defects are analysed by online condition monitoring system.

Conclusions

The findings from this pilot study have been enthusiastically received. Particularly noteworthy is the identification of immediate attention-worthy defects, such as broken rails, which are pivotal in minimising disruptions for passengers. While the demand for predictive maintenance capability persists, this solution has demonstrated its invaluable role in promptly detecting critical issues, thus enhancing operational efficiency and passenger experience.

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Estimating residual risks for railbreaks

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Introduction

A scenario is considered where a derailment has caused damage to the rail. Inspections are carried out, but there remains an uncertainty whether there is still damage to the rail. This mainly concerns the rail foot where cracks are difficult to detect in general and even more so in winter conditions. Further, induced rail foot defects tend to be more severe than rail head cracks due to the higher tensile stresses in the foot.

The study investigates the loading of a rail foot crack with the objective to assess which cracks that are likely to break at initial test operations, and how long remaining cracks are likely to survive.

Analysis

A fracture mechanics approach is taken where fracture occurs when

$$K_I \approx K_{Ib} + K_{It} + K_{Ir} \geq K_{Ic} \quad (1)$$

where K_{Ib} is the stress intensity due to rail bending, K_{It} due to temperature loading and K_{Ir} due to residual stresses. Ignoring K_{Ir} (which will increase the risk for rail breaks at welds) the fracture criterion may be simplified as

$$K_I \approx (\sigma_b + \sigma_t) f \sqrt{\pi a} \geq K_{Ic} \quad (2)$$

where f is a geometry factor, a the crack size, σ_b and σ_t are peak bending and thermal stresses at wheel passage.

Further, crack growth is estimated using Paris law

$$\frac{da}{dN} = C(\Delta K)^m \quad (3)$$

where $\Delta K = K_{\max} - \max\{K_{\min}, 0\}$, C and m are material parameters, and max is taken over a load cycle. Note here that the temperature stress is quasi-static.

Conclusions

It is shown how it is very difficult to provoke fracture during a test run since increased bending loads (due to overloaded vehicles) correspond to rather moderate decreases in temperature and/or larger defects.

At the start of operational traffic, remaining cracks will continue to grow. It is shown how the time to fracture is highly affected by temperature and that remaining defects may pose a long-lasting issue.

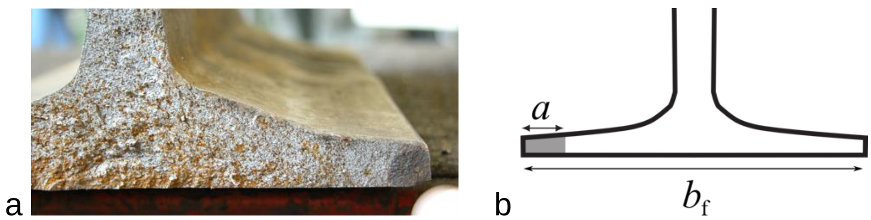

Figure 1. a) Rail break from foot crack (picture Anders Frick) and b) definition of idealised foot crack of size *a*.

Predicting Climatic Failures in Railway Infrastructure utilizing Machine Learning

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Introduction

Railway infrastructure assets, particularly assets like switches and crossings (S&C), are vulnerable to various operational and environmental hazards [1]. Changes in temperature and precipitation patterns and extreme weather events caused by climate change intensify risks and vulnerabilities and contribute to diverse failure modes [2]. Therefore, the classification of failures into climatic and non-climatic failures is essential for failure analysis, risk, life cycle cost assessment and developing climate adaptation measures for railway infrastructure assets [3]. This paper explores the potential of machine learning (ML) algorithms to predict climatic failures for railway infrastructure assets, leading to better risk management and proactive operation and maintenance decisions.

Analysis

The study utilised a comprehensive dataset of 128,504 recorded failures (25,858 climatic, 102,646 non-climatic) compiled from a variety of sources, including railway failure databases, asset registry, and meteorological records. Text mining techniques were used to define the Climate ID indicator. A selection of advanced ML algorithms, including LightGBM and XGBoost, were evaluated for their ability to predict climatic failures with optimal accuracy and performance. The primary result showed that Random Forest (RF) performed best, with an accuracy of 80% and a sensitivity of 74%. Furthermore, the analysis reveals an increasing trend of climatic failures for North and Middle region of Swedish railway network over the period.

Conclusions

This study demonstrates the application of ML algorithms for prediction of climatic related failures of railway infrastructure assets. The proposed solution helps infrastructure managers to make informed decisions for planning, operation, and maintenance while considering climate risks. The detailed breakdown of failure data highlights the urgent need to develop climate adaptation measures to improve the resilience of railway systems to climate change hazards and risks.

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A framework for climate adaptation of railway infrastructure

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Introduction

Various research studies have been performed to evaluate the impact of climate change on railway infrastructure (Thaduri et al., 2021). They concluded that railways have vulnerabilities that will be affected by changes in climate. Strategies for climate adaptation measures should be studied and developed. System innovation approaches should be investigated to identify barriers for implementation of solutions. The purpose of this research was to identify, describe and evaluate different aspects of system innovation related to implementation of actions that adapt the railway infrastructure to climate events. The objective was to design a framework that consider aspects of system innovation when implementing climate adaptation actions for railway infrastructure.

Analysis

Stamos et al. (2015) consolidated adaptation measures for transportation systems related to extreme weather events which resulted in a measure and policy database. Five aspects of system innovation (Miedzinski et al., 2019) related to climate adaptation solutions have been investigated (Jägare et.al., 2024). Previous work was compiled, evaluated, and expanded in this study, which utilises interview-based research to collect insights from experts within railway infrastructure and climate adaptation. The result is a framework that describes climate adaptation measures for railway infrastructure flooding hazards from a system innovation perspective. Research shows that challenges are related to, e.g., responsibilities, collaboration, allocation of money and resources, strategies and measurable objectives.

Conclusions

Climate change impacts the railway infrastructure. Implementation of climate adaptation strategies are necessary. The proposed framework explains, and guides implementation of climate adaptation actions related to climate change.

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