# Optimising wheel and rail economy by non-uniform rail grinding

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## Introduction

Managing rolling contact fatigue, RCF, and rail corrugation through rail grinding is nowadays standard practice. When the rail grinding machine passes over the track, they also change the shape of the rail profile. In Sweden non-symmetric tolerances are used for the target profile. On the rail shoulder the tolerance +0/-2ε is used, whereas on other surfaces the tolerance is symmetric ±ε. This lowers the rail shoulder, and reduces the risk of RCF by moving the load towards the top of rail. Here the contact area is larger and thus the contact pressure lower, increasing the resilience towards RCF.

Although beneficial for RCF, the reduced contact at the rail shoulders also leads to lower wheel wear at the flange root. The wheel wear becomes more concentrated on the thread, which is believed to cause hollow wear and increasing equivalent conicity with wear. With increasing conicity the margin towards bogie instability decreases, and preventive reprofiling of the wheels is necessary to avoid bad ride comfort.

## Suggested solution

The following non-uniform grinding scheme is proposed:

- On tangent track sections the rails are ground with a symmetric tolerance over its whole surface. Rail shoulders located at their nominal height will lead to wear in the flange root. This will prevent the wheels wearing to a high conicity shape.
- In curves the rails are ground with an asymmetric tolerance as today in order to keep the risk for RCF at a minimum.

The problem regarding RCF on rails are mainly in curves because the curve geometry leads to an increase in tangential creepages, and the tangential shear stresses is added to the normal contact stress. When the contact and shear stress exceed a certain threshold value RCF is initiated, and existing cracks will grow. On tangent track sections this is less of a problem, since the tangential stresses are much lower. The contact patch is located more towards the top of the rail, where the contact patch normally is larger.

The effect of the proposed solution on wheel wear and RCF is demonstrated by wheel wear loop simulations, and the effect on the economy of the total wheel-rail system is discussed. This work is one of the on-going research activities within the collaboration project "A systematic approach to improve passenger ride comfort", Asplund et al. (2023).

## References

M. Asplund et al., "Introduction to the Collaboration Project: A Systematic Approach to Improve Passenger Ride Comfort", Trafikverket 2023/113404: 178508100-001, 2023.

# Simulation-Based Assessment of Railhead Repair Welding Process Parameters

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## Introduction

Maintenance of the rail system includes repair of discrete rail head defects. In this study, repair welding of rail heads is investigated, and the risk for fatigue crack initiation for the repaired rail when in operation is estimated.

## Analysis

A process parameter study is carried out on the Swedish stick-welding rail head repair procedure focusing on preheating, operation temperature conditions and variations in repair geometry. The simulation methodology from Andersson et al. (2023) is used. It includes a 3D heat transfer analysis and a 2D generalized plane strain mechanical analysis, see Figure 1a. The heat source model is calibrated using measurements from a railhead repair welding experiment. To further assess the repaired rail section, mechanical rolling contact simulations based on typical traffic conditions are performed to estimate the risk of fatigue crack initiation at the repaired rail using the multi-axial Dang Van stress criterion.

## Conclusions

The weld repair process is robust; the powerful final zig-zag weld passes provide effective resilience against variations in additional heating. Further, in agreement with field observations, the simulations identify the interface zone of the base material and weld filler material as the critical region of the repaired rail in operation, see Figure 1 b,c.

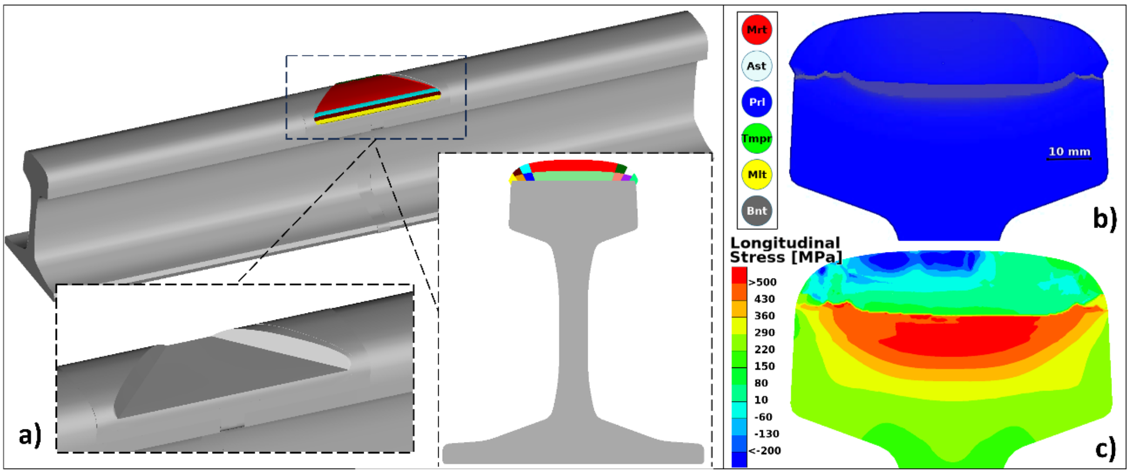


Figure 1. a) FE-model of the rail head with weld passes modelled. b) predicted material phases. c) calculated residual longitudinal residual stress after over-rolling operation.

## References

Andersson, B., Ekh M., Josefson B. L., “Computationally efficient simulation methodology for railway repair welding: cyclic plasticity, phase transformations and multi-phase homogenization”, Journal of Thermal Stresses, Vol. 47, pp. 164-188, 2023

# RCF crack propagation predictions

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Rolling contact fatigue (RCF) cracks in railway wheels and rails are costly and complex to deal with. Despite all the extensive research efforts that have been put into understanding these phenomena, there are still large uncertainties, especially regarding the direction and rate of RCF crack propagation. One reason is that the existence of the non-proportional mixed mode loading makes the predictions very complicated.

In this study, a 60E1 rail profile with an inclined semi-circular stationary surface-breaking gauge corner crack is subjected to multiaxial wheel–rail contact load, rail bending load, and thermal load (both individually and in combinations). The crack faces are frictionless, and the bulk material is modelled as linear elastic. Stress Intensity Factors (SIFs) are computed using a method developed by Andersson et al. (2018). Crack growth directions are evaluated using a vector crack tip displacement criterion developed by Salahi Nezhad et al. (2023). Crack growth rates are estimated using Paris-type equations.

Employing the full 3D geometry allows realistic load and crack conditions but increases complexity in crack modelling and predictions. To better understand the interplay between influential parameters and mechanisms in crack growth, predicted crack growth directions and rates are evaluated at different points along the crack front (see Figure 1) for different crack radii, and crack plane inclinations.

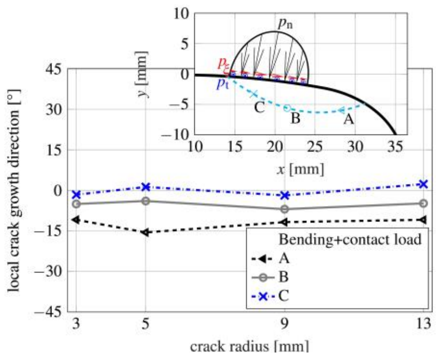


Figure 1. Predicted growth directions for a 3D rail crack with inclination $\varphi_0 = -25°$ w.r.t. longitudinal rail axis under a combination of bending and contact load (for a 7.5 t wheel load with traction coefficient $f_{wr} = 0.3$). Results are shown for three points (A, B and C) along the crack front.

## References

Andersson, R., Larsson, F., Kabo, E. "Evaluation of stress intensity factors under multiaxial and compressive conditions using low order displacement or stress field fitting", Engineering Fracture Mechanics, 189, pp.204–220, 2018

Salahi Nezhad, M., Larsson, F., Kabo, E., Ekberg, A. "Numerical prediction of railhead rolling contact fatigue crack growth", Wear, 530–531, 205003, 2023

**Abstract: Project for rail head conditioning with AI**

**Introduction**

The tramway operator Bernmobil, PROSE and LeanBI are jointly developing a system for on-demand rail head conditioning of trams. This research project is funded by the Swiss Federal Office of Transport (BAV) and will last from the beginning of 2023 until around mid-2025.

**Aim of the project**

The aim of the project is to achieve optimum conditioning of the rail head with the help of sensor technology and artificial intelligence (AI). In this context, the optimum is a needs-based dosage of the conditioning agent, which on the one hand leads to minimal wear on the wheel and rail as well as minimal noise emissions and on the other hand avoids "overlubrication effects".

**Ecological and social perspectives**

Overlubrication effects must be considered from an ecological and social perspective. For example, if too much conditioning agent is used, the environment is unnecessarily polluted and the conditioning agent adhering to the rail is picked up and further distributed by traffic or pedestrians when crossing the rails. Furthermore, overlubrication can lead to a black coating on the rail head or to flat spots or polygon formation of wheels.

**Solutions to avoid overlubrication**

By installing special sensors on the vehicles and tapping relevant data from the vehicle bus, the condition of the infrastructure and rolling stock can be determined to derive the need for lubricant. The resulting flood of data is evaluated and processed by artificial intelligence. Through continuous training with the increasing amount of data, AI can recognize when and where there is a need for rail head conditioning on the Bernmobil rail network based on data trends and correlations. The command and location of the rail head conditioning to be carried out is then transmitted via an IoT gateway to vehicles on which a mobile rail head conditioning system is installed. As soon as such a vehicle reaches the corresponding location on the route network, it conditions the rail head.

**Transfer of recorded data**

The recorded measurement data is fed into an AI model that is run on a computer in the vehicle to determine the need for conditioning. The corresponding commands are then transmitted directly to the rest of the vehicle fleet. The decentralized edge solution offers advantages such as lower latency, higher data security and lower bandwidth costs, as the data is processed directly locally.

**Improvement of AI model**

Nevertheless, relevant measurement data from all vehicles is transmitted to a central storage unit via the IoT interface. Depending on the resolution and sampling rate of the individual signals, the resulting data volume (big data) can be between 1.5 and 110 GB per vehicle and year. This data is used to successively train the AI model. If necessary, the existing AI models on the vehicles can be updated remotely by the

improved AI model. Since the commands of the rail head conditioning are determined directly by the Edge solution and the AI models running on the vehicles, the transmission of this data to the central storage unit does not have to take place immediately and continuously during operation but is also possible during downtimes in the depot.

**Benefits**

With the help of the AI, the large amount of data is converted into a comprehensible, interpretable data set (smart data) and visualized in a dashboard through corresponding representations. The commands generated by the AI can then be checked by experts and plausibility checked with the help of existing empirical values.

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# Advancements in Railway Ballast Inspection Methodologies and Technologies: A Comprehensive Literature Review

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## Introduction

The significance of the railway ballast bed for the overall performance of the track system is widely known. Ballast bed condition should therefore be minutely assessed so that the necessary maintenance activities could be initiated to minimize deficiencies and optimize ballast performance. Several studies have over the years been conducted to define and investigate how railway ballast performance is affected, for instance, how ballast fouling, or ballast breakage affects track settlement or drainage. However, only a few studies have focused on comparing different assessment methodologies, encompassing both destructive and non-destructive technologies, along with their strengths, weaknesses, and feasibility.

## Analysis

This study will review and describe current practices in assessing ballast condition, and their actual application in various countries relevant to this domain. In addition, a comprehensive literature review will be conducted, utilizing databases such as ResearchGate, ASCE Library, Scopus and Oria to examine the state-of-the-art methodologies and research. Subsequently, a comparative analysis will be undertaken, with the Norwegian rail network and climatic conditions serving as benchmarks.

## Conclusion

Traditional assessment techniques, i.e., visual inspection, trial pitting, and ballast sampling, although convenient and widely used, are affected by bias, and do not encompass large track sections at a time. The latter does provide a detailed information regarding ballast quality, such as gradation, bulk density, particle shape, particle surface texture, etc. This, however, requires further laboratory analysis. More advanced technologies such as Ground-Penetrating Radar (GPR), Falling weight deflector (FWD), Light Detection and Ranging (LiDAR), advanced track geometry data analysis, etc., offer non-destructive alternatives and can be executed with rail-going machinery, thus covering greater track sections. However, requires post-processing and do not give a comprehensive account of the ballast material quality.

Furthermore, it is expected to find significant distinctions between the available technologies for ballast assessment, the requirements and practices for ballast inspection set by several infrastructure managers, i.e., the difference between theory and practice. It is also expected to find disadvantages that have previously been overlooked.