Top-of-rail lubricants for the wheel-rail contact

Boukhris Rahma[1], Bergseth Ellen[2] Olofsson Ulf[3]
[1] Machine Design Department, KTH, Stockholm, Sweden. boukhris@kth.se
[2] Machine Design Department, KTH, Stockholm, Sweden. bergseth@kth.se
[3] Machine Design Department, KTH, Stockholm, Sweden. ulfo@md.kth.se

Introduction

Friction management is crucial for wheel-rail contact as high friction can reduce the life of the wheels and rails and too low friction can result in unacceptably long braking distance risking safety. To achieve intermediate friction levels, one may apply top-of-rail (TOR) lubricants to the rail head or add laser-clad (LC) coatings on the rail steel. Less evaluated is how these methods affect the airborne particles generated from the wheel-rail contact. High concentration of these particles is identified as a problem at underground train platforms.

Analysis

A pin-on-disk machine was used to evaluate the friction and airborne wear particles of the wheel-rail contact for three conditions: dry, lubricated with TOR lubricant, and laser-cladded (LC) rail steel disks with a Ni powder alloy containing 8% MnS. Tests were performed at two contact pressures: 0.3 GPa and 1 GPa. One of the LC disks got surface cracks after testing at 0.3 GPa. The average coefficient of friction decreased from 0.5 to almost 0.2 with the TOR lubricant and the non-cracked LC disk, while it only slightly decreased for the cracked LC disk. Crack might have occurred due to a sub-efficient LC process. The total particle number decreased with TOR-lubricant and LC disks compared to the dry condition, a significant decrease at 1 GPa. Furthermore, at high pressure, the TOR lubricant decreased the concentration of large particles (> 0.8 µm).

Conclusions

Top-of-rail lubricants and LC methods show promising results in controlling friction and decreasing particle emissions. However, further studies are needed to prevent too low adhesion, crack issues and the application and robustness in the field.

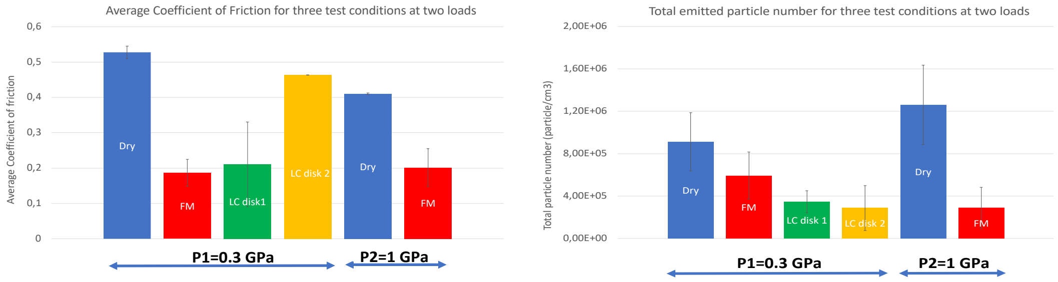

Figure 1. Average coefficient of friction (Left) and Total emitted particle number (Right) for the three test conditions at two loads.

A more data driven approach to friction management, using a new railhead tribometer

B. White[1], M. Watson[1] and R. Lewis[1]
[1] The University of Sheffield, bwhite2@sheffield.ac.uk

Introduction

If the wheel/rail friction coefficient is too low it can impede traction and braking and cause damage, delays and safety incidents. High friction can lead to reduced wheel/rail lifespan and excessive fuel consumption.

Friction management strategies, such as rail cleaning or lubrication, are used to ensure that braking is predictable and optimised, whilst maximising wheel and rail lifespan. These strategies can be costly and sometimes environmentally destructive, yet a trial-and-error approach is used due to the lack of portable measuring equipment. This work uses a new tribometer developed by Rivelin Rail to quantify rail condition and the effectiveness of friction management. Results are validated against full scale field and laboratory measurements.

Analysis

The Rivelin Rail portable railhead tribometer is magnetically clamped to the railhead and uses representative contact conditions (ER8 wheel steel, 1 GPa contact pressure, 1-8% creepage). An image of the tribometer and example results (before and after railhead cleaning) are shown in Figure 1.

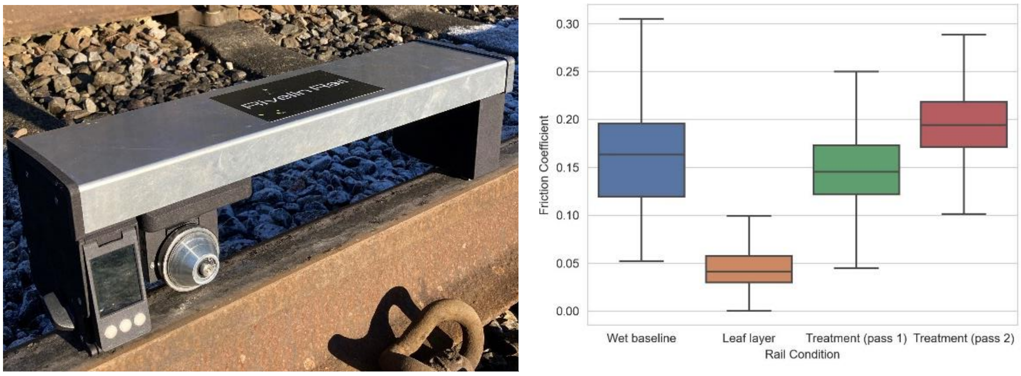

Figure 1. The Rivelin Rail portable railhead tribometer (L); example results (R)

Conclusions

The new tribometer was used to quantify a range of railhead conditions, including ultra-low friction that caused operational low adhesion. The effectiveness of other friction management strategies can be optimised using this method, essential for a high capacity and low carbon railway.

A Machine Learning Approach for Rail Friction Estimation

Roger Lewis[1], Morinoye Folorunso[1], Mike Watson[1], Paul Gray[2]
[1] Dept. of Mechanical Engineering, University of Sheffield, Sheffield, UK.
[2] Rail Safety and Standards Board, The Helicon, One South Place, London, UK.
Roger.Lewis@sheffield.ac.uk, mofolorunso1@sheffield.ac.uk, mike.watson@sheffield.ac.uk, paul.gray@rssb.co.uk

Introduction

Low adhesion in Autumn can lead to many problems for railway networks. It presents a safety problem as braking can be affected causing signals passed at danger and station overruns and in the worst case a train collision (RAIB, 2023). It also has an impact on service performance as acceleration is reduced and braking times are increased. This leads to train delays and passenger dissatisfaction. Railways use many different methods for mitigation, both applied wayside and from on-board trains. To optimise the approaches used, however, more knowledge is needed of friction conditions on the railhead, ideally presented near to real time. The aim of this work was to develop a machine learning based approach for estimating friction based on input information gathered from the railhead and its surroundings.

Outcomes from the Work

In the first stage of the work field measurements were carried out to capture railhead and forward facing images (of track surroundings) along with railhead temperature and air temperature and humidity (key parameters affecting friction in the wheel/rail interface (Folorunso et al., 2023)) and the corresponding friction values. Neural networks were then trained with this data and used, with a regression model, to develop a tool for friction estimation. The model was trained with part of the dataset and validated with the rest. The model has been trained with a range of low adhesion conditions including leaf layers and "wet-rail" conditions (oxide and water mixtures).

Figure 1 Camera Box on a Train

A camera box has been developed with temperature and humidity sensors which can capture all the input data for the model from a moving train. This has been trialled on the main network in the UK. An online version of the model is also available for rail industry staff to use with input information they have gathered in the field from low adhesion problem sites.

Conclusions

An AI based rail friction estimation tool has been developed and validated which could have wide application within the railway industry in planning mitigation for low adhesion in Autumn and enabling a fast response to problems that occur. Hardware has been engineered to allow data capture from a moving train which could eventually allow real time friction information to be relayed to train operations teams.

References

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Field Testing of Laser Clad Rails

Kate Tomlinson, Roger Lewis, Ruby Kempka, Kazim Yildirimli, David Fletcher
Dept. of Mechanical Engineering, University of Sheffield, Sheffield, UK.
Kate.Tomlinson@sheffield.ac.uk, Roger.Lewis@sheffield.ac.uk, r.kempka@sheffield.ac.uk, kyildirimli1@sheffield.ac.uk, D.I.Fletcher@Sheffield.ac.uk

Introduction

Laser cladding of rail, that involves the application of a layer of premium material on standard grade steel has been investigated in small (Lewis et al., 2016; Wang et al., 2016) and full-scale laboratory tests (Lewis at al., 2017) and shown to give a significant improvement in wear and rolling contact fatigue performance. Clad layers on rail either side of an insulated block joint (IBJ) can also reduce the lipping effect that can cause track circuits to fail (Lewis at al., 2017). In order to improve industry confidence and allow the technology to pass the rigorous approvals processes required for network trials, the cladding needed to be assessed in the field in offline testing. The aim of this work was to test rail sections different clad layers in the field and benchmark them against premium rail materials while also assessing actual IBJ performance with clad layers.

Results

A string of rail sections with either Stellite 6 or martensitic stainless steel clad layers along with unclad R260 standard grade rails and HP rail was assembled using IBJs and inserted into track at the British Steel plant at Scunthorpe (see Figure 1). The rails have been in-situ now for over three months. Periodically a series of measurements have been undertaken to assess the performance of the rail sections and the IBJs. 3D laser scans have been taken allowing accurate wear volumes to be determined. The amount of gap closure for the IBJs has been measured as well as hardness of the rail surfaces. The indications so far are that the clad layers are performing best followed by the premium and then standard grade rail. The rails will remain in situ to assess long term performance of the layers and to generate data to feed into approvals processes and a cost benefit analysis to allow infrastructure owners justify their use.

Figure 1 IBJ String

Conclusions

Field tests of laser clad layers on standard rail steel are showing that they offer greatly improved wear resistance over both premium and standard grade rails and that the problem of lipping at IBJs has also been reduced.

References

Lewis, S.R. et al. (2016) ‘Improving rail wear and RCF performance using laser cladding’, Wear, 366-367, pp268-278.

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Optimisation of crossing panel design for reduced environmental footprint

Henrik Vilhelmson[1], Björn A. Pålsson[1] and Jens C. O. Nielsen[1]
[1] Department of Mechanics and Maritime Sciences, Chalmers University of Technology,
SE–412 96 Gothenburg, Sweden
Henrik.Vilhelmson@Chalmers.se

Introduction

A fixed crossing allows for trains to pass over two intersecting tracks. The conicity of the wheel in combination with the variation in rail geometry along the crossing panel results in a wheel–rail excitation that is characterised by a dip angle in the vertical wheel centre trajectory. This excitation will induce a wheel–rail impact load, which may lead to damage of wheels and rails, noise and vibration, rail fatigue due to bending, sleeper cracking and differential settlement of ballast.

Analysis

A structural finite element (FE) model of a crossing panel has been created. Based on the Craig–Bampton substructuring approach, the model is converted to the Multi Body Simulation (MBS) software Simpack's FlexTrack format to allow for simulations of dynamic vehicle–turnout interaction. By introducing sleeper-ballast voids and variable track stiffness parameters, the model has been calibrated and verified against measured data from an Austrian demonstrator. Using the verified model, a parameter study and an optimisation of the crossing panel design is carried out aiming to reduce CO_2 emission from the production while maintaining all operational and structural requirements.

Conclusions

The model shows very good correlation to the measurement data after calibration of physical track parameters. The results of the parameter study are presented as a response surface. From the optimisation, it is shown that the mass (dimensions) of the sleepers and crossing rail can be substantially reduced while fulfilling all structural constraints.

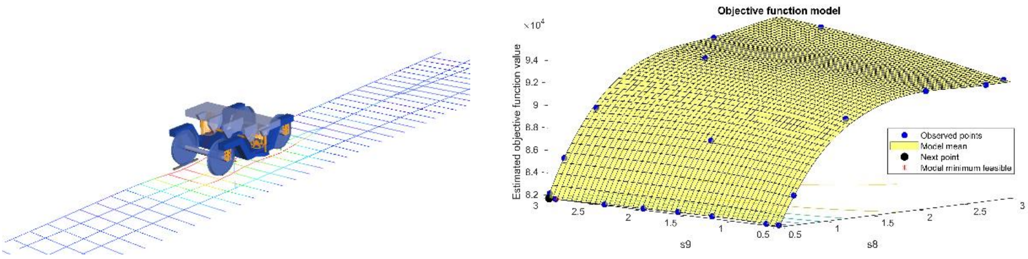

Figure. a) MBS model in Simpack. b) Response surface of CO_2 emission for two track stiffness parameters.