Friction, wear and particle emissions from copper-based train brakes

Yezhe Lyu[1], Leonie Tanzeglock[1], Qixiang Zhang[2,3], Francesco Varriale[1,4], Jiliang Mo[2,3], Joakim Pagels[5,6] and Jens Wahlström[1]

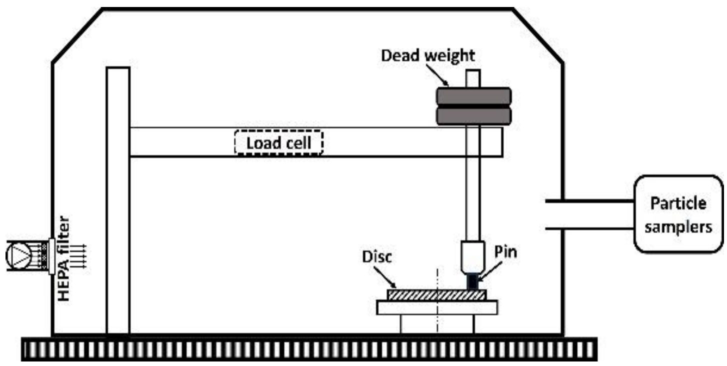
[1] Department of Mechanical Engineering Sciences, Lund University, Lund, Sweden.
[2] School of Mechanical Engineering, Southwest Jiaotong University, 610031 Chengdu, China
[3] Technology and Equipment of Rail Transit Operation and Maintenance Key Laboratory of Sichuan Province, 610031 Chengdu, China
[4] Brembo S.p.A., 24040 Stezzano (BG), Italy
[5] Ergonomics and Aerosol Technology, Lund University, 221 00 Lund, Sweden
[6] NanoLund, 221 00 Lund, Sweden

Introduction

The disc brake system is one of the most important mechanical brake systems on railway vehicles. A significant aspect of the railway disc brake system which has been overlooked until now is the emission of airborne particles during the braking process. This study aims to map the friction, wear and airborne particle emission dependence on the train speed and braking pressure.

Method

A pin-on-disc (PoD) tribometer placed in a one-way ventilated enclosure was used to replicate the sliding contact between brake pad and disc materials of high-speed trains. Two particle spectrometers were employed for the online measurement of particle emissions. The first one was a TSI® aerodynamic particle sizer (APS) model 3321, covering particles ranging from 370 nm to 20 µm. The APS measured the particle number concentration (PNC) up to 10 000 particles/cm^3 and particle size distribution at 32 size-resolved channels, using an air flow rate of 1 L/min. The other one was a TSI® condensation particle counter (CPC) model 3775, which measured only PNC within the size range from 4 nm up to 3 µm.



Sketch of the experimental setup.

Results and conclusions

Experimental campaign will be carried out soon, and the results and conclusions will be presented at the 22nd Nordic Seminar on Railway Technology.

Long-term performance of railway brake discs for high-speed postal wagons: wear and fatigue

Mandeep Singh Walia[1], Andreas Lundin[2] and Lars Ferhlund[3]
[1] Locomotive division, Green Cargo AB, Solna, Sweden. mandeep-singh.walia@greencargo.com
[2] Wagon division, Green Cargo AB, Solna, Sweden. Andreas.Lundin@greencargo.com
[3] Locomotive division, Green Cargo AB, Solna, Sweden. Lars.Fehrlund@greencargo.com

Short delivery times of freight cargo put demands on high vehicle speed, which in turn requires a high performance of the braking systems. Continuing the work from previous experimental studies, different friction pairs are analysed for long-term usage in traffic. With speeds up to 160 km/h, postal wagons equipped with cast iron non segmented brake discs (reference disc) and enhanced grey cast iron material "segmented" brake disc (friction rings built from five identical sectors) have been analysed. Two different brake pad materials: sinter and organic composite were studied. Long-term performance was analysed based on wear and fatigue characteristics. Wear measurement for brake discs were made by using Calipri. Crack formation and severity of cracks on disc surface were studied. Results provide a good insight to the long-term performance of the brake discs and preferred friction pairs.

Figure 1. Cracks on non-segmented disc (left) and segmented disc (right) for long-term usage.

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Thermomechanics of the brake – wheel – rail system: Results from two tread brake roller rigs

Eric Voortman Landström[1], Tore Vernersson[2] and Roger Lundén[3]
[1] M2/CHARMEC, Chalmers University of Technology, Gothenburg, Sweden. ericlan@chalmers.se
[2] M2/CHARMEC, Chalmers University of Technology, Gothenburg, Sweden. tore@chalmers.se
[3] M2/CHARMEC, Chalmers University of Technology, Gothenburg, Sweden. rolu@chalmers.se

Introduction

The thermomechanical behaviour of the brake – wheel – rail system is difficult to characterize because of the complex loading state, combining rolling contact due to the wheel–rail interaction with the thermomechanical interaction from the wheel–brake sliding contact. By combining the existing Chalmers Brake Rig with a new rail module, this interaction has been studied for some drag tread braking cases by use of a high-speed thermographic camera. In addition, measurements have also been performed for stop braking experiments in the tread brake roller rig at the Railway Technical Research Institute of Tokyo, Japan.

Analysis

The thermographic imaging is synchronised with wheel rotation. Discrete areas of increased temperatures are identified in which the material is weakened, which was shown in Voortman Landström et al (2023). Results from thermographic measurements are compared to local variations in tread damage and wear as characterized upon cooling down after braking.

Conclusions

The performed experiments show the importance of accurate characterization of the thermomechanical interaction in the wheel–brake–rail system. Thermographic imaging allows for capturing of the detailed temperature field, which can be correlated to wheel damage in post-test measurements. Similarities and differences between drag braking tests and stop braking tests performed in brake rig environments are highlighted.

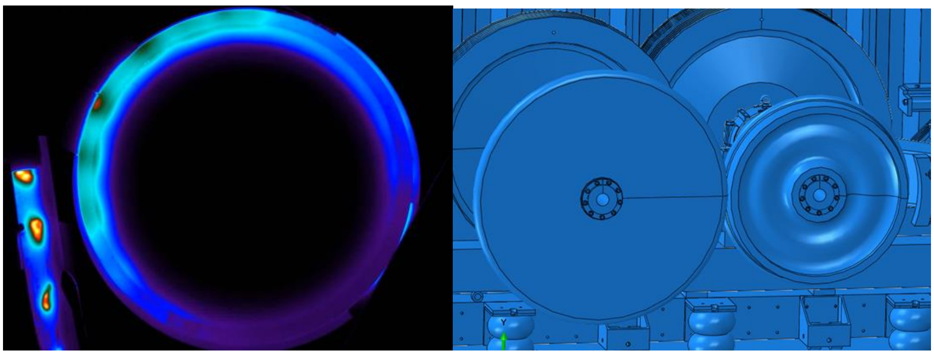

Figure 1: a) thermographic image of freight wheel, b) CAD model of the Chalmers brake rig.

References

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Braking performance of freight trains

Francesco Mazzeo[1], Bastian Schick[2], Mats Berg[2] and Stefano Melzi[1]
[1] Dep. Mechanical Engineering, Politecnico di Milano, Milan, Italy
[2] Dep. Engineering Mechanics, KTH Royal Insitute of Technology, Stockholm, Sweden
francesco.mazzeo@polimi.it

Introduction

Rail transport is considered a cost-effective and eco-friendly solution for long-distance freight, contributing less than 1% to overall transportation pollution [1]. In pursuit of efficiency, using longer and heavier freight trains is crucial for increased delivery without compromising transport times. However, safety concerns emerge with longer trains due to high longitudinal compressive forces (LCF) during especially emergency braking [2-3]. This paper analyses various braking strategies, examining their impact on LCF to ensure running safety and train integrity.

Analysis

In Europe, freight wagons utilize the UIC pneumatic brake system (P-brake), where brake and release signals travel by means of pressure waves through the Main Braking Pipe (MBP), resulting in substantial delays for long trains. This contributes significantly to large longitudinal compressive forces (LCF) during braking, compromising running safety and limiting the maximum length of the trains [2-3]. Recently, the European DAC Delivery Program by Shift2Rail aims to upgrade freight wagons with the Digital Automatic Coupler (DAC): an innovative component that automatically couples and decouples the rolling stock in a freight train both physically, for the mechanical connection and the air line for braking, as well as digitally. The digital connection through the train will allow the implementation of the electronically controlled pneumatic (ECP) brake, which overcomes the delays of the braking action, reducing drastically the LCF and allowing longer and safer trains.

This paper investigates the longitudinal dynamics of freight trains, simulating emergency braking manoeuvres while taking into account the current state of the art of P-braking. The analysis incorporates the influence of payload dependence on brake action and explores the significant impact of various brake block materials on braking torque. Additionally, simulations of the same manoeuvres are conducted with ECP-braking in vehicles equipped with the Digital Automatic Coupler (DAC), allowing for a comparison of the final results. Finally, this paper shows the benefits of introducing the Digital Automatic Coupler in enhancing the performance of freight trains.

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Modelling the temperature development of a railway brake disc

Yanjun Zhang[1], William Liu[1] and Sebastian Stichel[1]
[1] Department of Engineering Mechanics, KTH Royal Institute of Technology, Stockholm, Sweden.
yanjunzh@kth.se, zhendong@kth.se, stichel@kth.se

Introduction

One component of the railway mechanical brake system is the brake disc, which converts the kinetic energy into thermal during braking. A high brake disc temperature reduces the coefficient of friction between the brake disc and pad, and induces thermal cracks. To avoid these negative impacts, it is necessary to understand how friction heat is generated and dissipated on the brake disc.

Analysis

This study focuses on modelling the temperature development of the brake discs. Based on the finite element method (FEM), a three-dimensional (3D), transient, thermal model is built. Different modelling methods, which differ mainly regarding heat input and friction area are studied and compared.

Simulation results for three different cases are shown in Figure 1. Case 1 is based on an analytical or empirical solution which disregards thermal expansion and wear of the brake pad. Case 2 and 3 are based on the FEM which can provide details of temperature and stress distribution. The numerical method based on the FEM provides more accurate results than the analytical/empirical method, but the computation is heavy. How to reduce computational time becomes an important issue for the implementation of the numerical method.

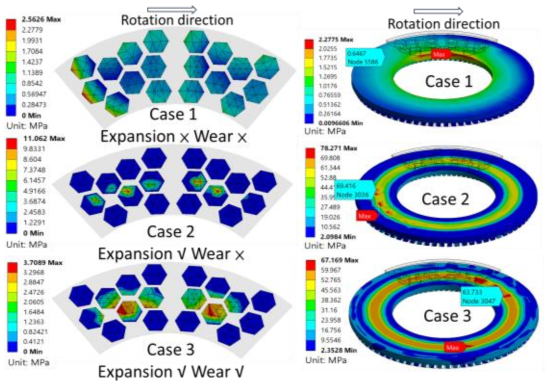

Figure 1. Contact pressure and equivalent stress of railway brake disc with respect to different methods and conditions.

Conclusions

Both thermal expansion and wear should be included in the thermal model of the railway brake disc. Braking is a multiphysics process: a coupled thermo-mechanical-fluid numerical model is required. Research on reducing computational effort is vital.