EB2016-SVM-040

THERMAL IMPACT ON ROLLING CONTACT FATIGUE AND THERMAL CAPACITY OF RAILWAY WHEELS

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KEYWORDS – railway wheel, tread brake, RCF, temperatures, numerical simulations, ratchetting strains

ABSTRACT
Research Objective: Tread braked railway wheels are subjected to complex loading due to rolling contact stresses and additional thermally induced stresses. The main objective of this study is to find the limits for tread braking with respect to temperature impact on rolling contact fatigue (RCF) of the wheel tread. For this study, one S-shaped wheel, used as reference case, and also one inclined-straight web wheel are studied for repeated and single stop braking cycles. Evolution of damage in the vicinity of the wheel tread is studied for various brake loading cases. The calculated damage is compared to previously developed critical damage levels, based on full-scale brake rig testing, in order to reveal limits for the tread braking.

Methodology: An axisymmetric FE model, developed and calibrated in earlier studies, is first used to analyse wheel temperatures when accounting for heat partitioning between brake blocks, wheel and rail. After this, a three-dimensional model of a 30° sector of a wheel is established to study effects from simultaneous thermal loading on wheel tread and mechanical loading introduced by wheel-rail rolling contact. In order to account for the elevated temperatures, the simulations utilise a viscoplastic material model. The mechanical loads account for frictional rolling contact stress distributions introduced by braking. Partial slip is considered and interfacial shear stresses are introduced in the wheel rail contact area. Ratchetting strains near the tread are studied and compared to the limits for total ratchetting, based on full-scale rig tests, to find the limits for braking and relate them to wheel temperatures and braking load cases. The braking load cases are defined on the basis of axle loads, decelerations, initial speed, initial wheel temperatures and brake block material. Influence of residual stresses in the wheel rim from manufacturing is considered.

Results: Results are presented for a parametric study with thermomechanical loading based on different braking load cases. Temperature distributions during simulated brake cycles are presented. From the simulations of combined mechanical and thermal loading, maximum effective strain rates and ratcheting strain per cycles are calculated. Ratcheting lives are assessed for the studied braking load cases. The results shows that the temperature has a strong influence on the rolling contact fatigue of railway wheel treads and, hence, on the thermal capacity of the wheels. The importance of operational parameters such as axle loads, initial speeds, decelerations and block material is presented. The calculated damage is related to global conditions relating to temperature and braking conditions in order to find limits for tread brakes.

Limitations of this study: The wheel-rail contact stresses are found by elastoplastic simulations of a vertical indentation problem. Based on the simulated normal stresses, the contact is partitioned into a stick zone and a slip zone, where in the slip zone a linear variation of shear stresses is presumed. Due to computational limitations, the entire thermomechanical braking cycle cannot be included in numerical simulations. Instead, mechanical loading is applied at specific instances during a braking cycle and the temperature is kept constant during those instances.

What does the paper offer that is new in the field in comparison to other works of the author: The present paper for the first time deals with an assumed in-field braking situations, whereas previously only brake rig conditions have been considered. Moreover, the influence from temperature-dependent material properties on wheel-rail contact area and contact pressures are now accounted for.

Conclusion: The study gives preliminary limits for revenue traffic, described as combinations of tread temperatures and wheel-rail rolling contact loading, that should be respected to avoid thermal cracking of railway wheel treads. The work constitutes a step towards understanding how temperature affects RCF damage developed at tread braking, which is a key towards controlling and prolonging the service life of tread braked wheels. With good assessments of RCF damage, the Life Cycle Costs (LCC) of the wheels could be reduced.