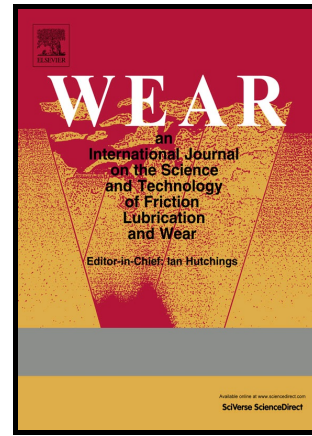


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Casey Jessop, Johan Ahlström, Lars Hammar, Søren Fæster, Hilmar K. Danielsen



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## 3D characterization of rolling contact fatigue crack networks

Casey Jessop<sup>1\*</sup>, Johan Ahlström<sup>1</sup>, Lars Hammar<sup>1</sup>, Søren Fæster<sup>2</sup>, Hilmar K. Danielsen<sup>2</sup><sup>1</sup>Department of Materials and Manufacturing Technology, Chalmers University of Technology, Gothenburg, Sweden<sup>2</sup>Department of Wind Energy, Technical University of Denmark, Risø Campus, Denmark

\*e-mail: casey.jessop@chalmers.se

## Abstract

Rolling contact fatigue (RCF) damage is becoming more frequent with increased traffic, accelerations, and loading conditions in the railway industry. Defects which are characterized by a two-lobe darkened surface and a V-shaped surface-breaking crack are defined as squats. The origination and propagation of squats in railway rails is the topic of many recent studies; the associated crack networks develop with complicated geometry near the surface of rails, but can be difficult to detect and distinguish from normally existing head checks in their early stages, using in-field non-destructive detection techniques. After cutting out damaged sections of rail, there are a number of options to characterize the damage. The aim of this study was to evaluate different methods to geometrically describe squat crack networks; through X-ray radiography complemented with geometrical reconstruction, through metallography, through X-ray tomography, and through topography measurements. The experiments were performed on squats from rail sections taken from the field. In the first method, high-resolution and high-energy X-ray images exposed through the entire rail head from a range of angles were combined using a semi-automated image analysis method for geometrical reconstruction, and a 3D representation of the complex crack network was achieved. This was compared with measurements on cross sections after repeated metallographic sectioning to determine the accuracy of prediction of the geometrical reconstruction. A second squat was investigated by X-ray tomography after extraction of a section of the rail head. A third squat was opened by careful cutting, which gave full access to the crack faces, and the topography was measured by stylus profilometry. The high-energy X-ray, 3D reconstruction method showed accurate main crack geometry at medium depths; the advantage of the method being that it potentially could be developed for non-destructive testing in field. However significant drawbacks exist due to limitations in radiography in terms of detecting tightly closed cracks in very thick components. This includes the inability to detect the crack tips which is an important factor in determining the risks associated to a specific crack. Metallographic investigation of the cracks gave good interpretation of crack geometry along the sections examined, and gave the possibility to study microstructure and plastic deformation adjacent to the crack face. However this time-consuming method requires destruction of the specimen investigated. The X-ray tomography revealed the 3D crack network including side branches in a 10x10x30 mm<sup>3</sup> sample, and provided topographic information without completely opening the squat. Topography measurements acquired by stylus profilometry provided an accurate description of the entire main crack surface texture, including features such as surface ridges and beach marks.

Keywords: Rolling contact fatigue; Optical microscopy; Electron microscopy; Profilometry; Radiography; X-ray Tomography

## 1. Introduction

Heavier loads and increased accelerations and speeds on today's railways are causing increasing damage to rails and wheels [1]–[3]. The early detection and correct categorization of surface and near-surface defects could help reduce the maintenance costs as well as frequency and intensity of failures and

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