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# Prediction of the coexistence of rail head check initiation and wear growth

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**Abstract:** A method for predicting the coexistence of the rail head check (HC) initiation and wear growth was presented to divide the continuous process of HC initiation and wear growth into many of the same discrete processes, each of which included wear and fatigue damage by wheel/rail stick–slip contact, wear-induced rail profile evolution, cumulative fatigue damage until a random material point in the rail reached the fatigue failure criterion. The method was applied to predict HC initiation for a U75V heat-treated rail, this being the sharp curve high rail used in China's heavy-haul railway, and was compared with the method considering no wear and validated by field tests. The result shows that the HC initiation life was about $2.17\times10^5$ wheel cycles and the average vertical wear growth rate was about 4.2651 μm/$10^4$ wheel cycles, values which were close to the field observation. Because the wear growth and profile evolution, the HC initiation position was closer to the rail center than when using the method considering no wear and the development of the fatigue damage was nonlinear from slow to fast .

**Keywords:** rail, fatigue, wear, head checks, initiation

## 1. Introduction

Rolling contact fatigue (RCF) cracks and wear on the rail surface are the two main kinds of defects which affect rail service life and train operation safety. The initiation and propagation of RCF cracks, such as head checks (HCs) and squats, and the growth of rail wear, reducing the metal and changing the profile of the rail head, influence each other. Their competition has been observed by field tests [1] and laboratory twin-disc machines [2–4]. The HC and wear should be considered together.

Existing research has been focused on either the wear, for example through Archard's wear law [5] or the wear number Tγ/A [6], or the RCF crack initiation, for example by the Dang Van multiaxial fatigue criterion [7] or the critical plane method [8–10].

Franklin et al. established a brick rail model based ratcheting failure [13,14] for simulating the plastic shear strain of material, together with wear, crack initiation and propagation. Then the effect of normal and tangential loading [15], the rail steel microstructure [16] and the thermoelastic [17] on the crack and wear were analyzed respectively. Trummer et al. [11–12] presented a model for the prediction of RCF crack initiation considering plastic shear deformation and wear by wear number and the frictional power per contact area respectively, which can be applied for predicting the damage pattern, either crack-dominated or wear-dominated, observed in a full-scale test-rig experiment. Daves et al. [18] presented a multi-scale finite element model (FEM) to simulate the deformation process causing RCF cracks and wear near the surface of a rail under rolling sliding contact. Dirks et al. [19] extended two kinds of RCF prediction models, based on the shakedown in combination with the Archard wear model for predicting both RCF and wear in the wheel. These models were applied for predicting the damage

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