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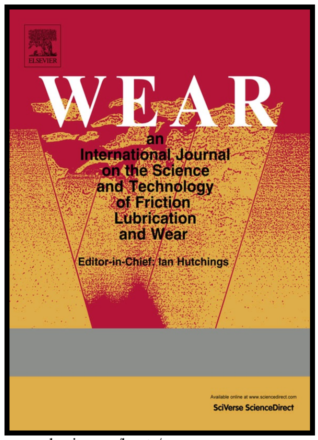

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PII: S0043-1648(18)30139-X
DOI: https://doi.org/10.1016/j.wear.2018.04.016
Reference: WEA102408

To appear in: *Wear*

Received date: 31 January 2018
Revised date: 25 April 2018
Accepted date: 26 April 2018

Cite this article as: Mohamad Ghodrati, Mehdi Ahmadian and Reza Mirzaeifar, Modeling of Rolling Contact Fatigue in Rails at the Microstructural Level, *Wear,* https://doi.org/10.1016/j.wear.2018.04.016

Modeling of Rolling Contact Fatigue in Rails at the Microstructural Level

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Abstract

A micromechanical-based finite element framework is developed to investigate the rolling contact fatigue (RCF) in rails. The microstructure of a representative part of the rail in contact with the wheel during wheel passage is modeled using Voronoi tessellation algorithm. The geometry explicitly represents microstructural grain and grain interface features that represent actual microstructure of rail steel. The grain interface is modeled using cohesive elements. For higher computational efficiency, moving Hertzian load is applied to the rail surface instead of moving the wheel explicitly on top of the rail. The jump-in-cycles approach is employed to efficiently simulate a large number of loading cycles, while the material degradation at the grain interface is represented by an accurate damage evolution law. Additionally, the model is used to evaluate the effects of temperature change, traction coefficient, and grain size on initiation and progression of RCF. The results indicate that colder temperatures increase the progression of RCF, while warmer temperatures do not have any significant effects. Large traction forces at the wheel-rail interface significantly accelerate RCF growth, mainly through migration of subsurface micro-cracks to the surface of the rail. The surface cracks grow into larger ones that lead to loss of rail material. Controlling the grain size can have a positive effect on both the initiation and migration of sub-surface cracks. Changing yield strength of material with the Hall-Petch relation, the model evaluates the effect of refining the grain size. The results indicate that smaller grains can improve RCF properties of the rail. The effect of maximum contact pressure on RCF is studied, and the results show a power relation between maximum contact pressure and RCF life. Also several case studies are simulated and compared with the experimental observations. The simulation results are in close agreement with the experimental observations for the crack pattern and crack depth.

Keywords: Rolling contact fatigue, Microstructure, Damage, Cohesive elements, Rail-wheel tribology, Finite element modeling

1. Introduction

Rolling contact fatigue (RCF) is a major source of failure, and a dominant cause of maintenance and replacements in many railways around the world. The cost of RCF defects to the United States and European rail system exceeds many millions of dollars annually [1-3]. The highly-localized stresses in a relatively small contact area at the