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Modeling of vertical split rim cracking in railroad wheels

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ABSTRACT

Vertical split rim cracking, due to rapid unstable propagation of a shallow sub-surface crack parallel to the front rim face, is one of the dominant mechanisms of railroad wheel failure. Wheel impact load is believed to be a trigger for this unstable crack growth. This rapid crack growth rate depends on several factors, such as wheel geometry (wheel diameter and rim thickness), load magnitude, load location, residual stresses in the rim, worn tread profile, and material defects in the rim (size, shape, location, and orientation). This paper develops a computational methodology to investigate the effect of these parameters on vertical split rim cracking, using finite element analysis and fracture mechanics. Vertical split rim cracking is modeled using a three-dimensional, multi-resolution, elastic–plastic finite element analysis. Material defects are modeled as mathematically sharp cracks. Wheel impacts are simulated by applying high mechanical loads on the tread surface. The residual stresses and wheel wear effects are also included in modeling vertical split rim cracking. The proposed computational methodology can help to predict whether a vertical split rim failure might be triggered for a given set of parameters, such as load magnitude, load location, wheel diameter, rim thickness, residual stress state, crack size, crack location, and crack orientation.

1. Introduction

In recent years, vertical split rim failure has become one of the dominant railroad wheel failure mechanisms observed in North America [1]. This failure is brittle in nature and occurs due to rapid unstable crack growth with a piece of either front or back of the wheel rim breaking off from the wheel [2].

1.1. Vertical split rim cracking

The vertical split rim crack can originate from existing tread damage (such as shell or spall cracks) or from a very shallow sub-surface crack [3]. The unstable propagation of a vertical split rim crack is believed to be triggered under wheel impact loading. Wheel impact loads can occur due to surface defects on the tread surface or due to track conditions, such as crossing diamonds [1]. This paper focuses on developing a computational methodology to model the vertical split rim cracking.

In the literature, very limited research has been published related to the vertical split failure in railroad wheels. Lonsdale et al. [1] have performed both computational and experimental work to understand the stress levels in the wheel rim under an impact load. This paper found that the load location close to the front rim face generates higher stresses in the rim. The finite element results estimated the axial stresses on the wheel tread surface along the taping line as tensile stresses with magnitudes of 200 MPa (29 ksi) and 393 MPa (57 ksi) for wheels with rim thicknesses 38.1 mm (1.5 in.) and 22.225 mm

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