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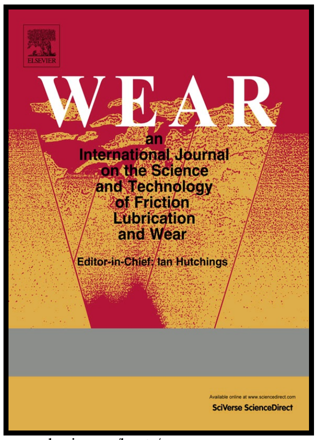

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Multiscale characterization of head check initiation on rails under rolling contact fatigue: mechanical and microstructure analysis

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ABSTRACT

Head Check is a major rolling contact fatigue (RCF) defect initiated after cyclic wheel/rail contacts by severe plastic deformation of the rail head surface. A field analysis campaign has been conducted on a site affected by Head Checking. The aim of this study is to increase understanding of the relationship between RCF cracking and plastic deformation of the pearlitic microstructure. Investigations are performed on samples taken at several stages of accumulated tonnage in the early stages of formation of the defect. To supplement previous characterizations of Head Checking and studies of damage mechanisms, several investigations have been carried out with a microstructural point of view. Following a multi-technical and multi-scale characterization of the worn rail surface, this experimental methodology has been based on the combination of several microstructural investigations by optical and scanning electron microscopy (FEG-SEM), microindentation performed on the gradient profile and determination of quantitative data on the pearlitic aggregates through the gradient by Electron Backscatter Diffraction (EBSD). Due to the severe plastic deformation near the gauge corner of the worn rail, the microstructure is progressively modified. During the first cycles of wheel/rail contacts, a strong evolution of the decarburised layer is observed. In transverse sections, the ferrite phase is severely shear-strained and the cementite lamellae within the pearlitic colonies begin to bend in the shear direction. Severe misoriented areas (>10°) are observed in the proeutectoid ferrite, suggesting that the proeutectoid ferrite is more strained than the pearlite colonies in the first stages of accumulated tonnage. Near surface hardness increases with the total traffic load and the thickness hardness gradient becomes significant as rail experiences work hardening. At the early stages of development, surface rolling contact fatigue cracks are initiated in the soft ferrite phase. Cracks propagate progressively below the rail along the shear-strained ferrite phase at the boundary with pearlitic colonies. This improvement in rail Head Check defect characterization with a microstructure point of view and the study of its development will contribute to improve the understanding of the entire damage mechanism of Head Checking and the modeling of rail failure by RCF by implementing microstructural data.

Keywords: Rail; Rolling Contact Fatigue; Head check; Microstructure;Hardness

1. Introduction

Rolling contact fatigue (RCF) of rail steels is an important issue in modern railway networks, which is caused by the rolling-sliding action of the wheel on the surface of the rail. Due to the heavy cyclic contact loading, surface and subsurface cracks are initiated and can often be found in the form of specific RCF defects , the two major types of whom are Head checks and Squats. The mechanisms of crack initiation and propagation have been investigated for decades in order to increase understanding of RCF damaging. In the 1970s, British Rail Research undertook work on investigating the effect of material on RCF and wear behaviour of rails . From these analyses, it was understood that Head Checking is caused by cyclic, plastic deformation of the rail due to compressive and shear stresses acting at the wheel/rail contact surface. As the wheel/rail contact area is smaller in this configuration, Head Check defects are often found on the gauge corner of the outside rail of a curve (R < 2000 m). Pointner showed that there is a link between the appearance of RCF crack defects and the track radius. In this study, maximum RCF developments were found around radii of 1200 to 1500m. Typical Head Check network is characterized by cracks regularly spaced from 1 mm to few centimetres and oriented with a 45° angle in the shear direction. RCF defects propagation can either lead to the spalling of the rail surface layer or even to the brutal rail failure in the worst cases.

In the 1990s, the European research program ERRI D173 carried out field tests and investigations on different rail steels in order to improve control on RCF . More recent studies also showed that there is a strong influence of material properties and microstructure on RCF damage. In any case, RCF damage reduces the lifetime of the rail and increases maintenance costs, as a system of preventative maintenance partly based on rail grinding can be used to prevent rail failures . Grinding of new rails is also recommended shortly after installation in order to eliminate the decarburization layer and defects in rail surface caused by manufacturing, transport or laying. In practice, the first grinding operation is not always done after installation of a new rail for time and costs reasons. These surface defects and the decarburized