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Laboratory simulation of martensite formation of white etching layer in rail steel

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Abstract:

White etching layer (WEL) is a frequently observed microstructural phenomenon in rail surface, formed during dynamic wheel/rail contact. It is considered as one of the main initiators for rolling contact fatigue cracks. There are several hypotheses for the formation mechanism of WEL. However, due to the complicated wheel/rail contact conditions, none is directly proven. Currently, the most popular hypotheses refer to either formation of martensitic WEL by phase transformations or formation of nanocrystalline ferritic WEL by severe plastic deformation. In this work, WEL formation by martensitic transformation in R260Mn grade pearlitic rail steel was simulated by fast heating and quenching experiments. Microstructural characteristics of the simulated WEL and WEL observed in a field rail specimen were characterized by microhardness, optical microscopy, scanning electron microscopy and electron backscatter diffraction. Microstructures of the two WELs were compared and similarities in morphology were identified. Numerical simulation shows the possible temperature rise up to austenitizing temperatures. Combining comparisons of experimental simulation with observation of WEL in the rail and the thermodynamic calculations, the hypothesis for WEL formation via martensitic transformation is supported.

Keywords: white etching layer; martensite formation; laboratory simulation; temperature rise; thermodynamic calculations

1. Introduction

Rolling contact fatigue (RCF) is the dominant damage mechanism in rails and has attracted wide scientific interest. The high and repetitive external load, exceeding 1 GPa, leads to formation of peculiar surface structural alterations, surface crack formation and spallation [1,2]. One such specific structural phenomenon in rail surface is widely named white etching layer (WEL) [1–7]. WEL is commonly recognized as a thin and hard layer, which appears white under light reflection after being etched in 2 to 5% HNO_3 in ethanol (Nital etchant). Widely accepted opinion is that the extremely high hardness of WEL, up to 1200 HV [6], is related to its brittleness. RCF cracks associated with WEL are frequently observed in rails [2].

The most popular hypotheses for WEL formation are: *(i)* martensite formed after the rail surface is heated up to austenitization temperatures and subsequently quenched, e.g. [5], and *(ii)* nanocrystalline ferrite as a result of severe plastic deformation [4]. A brief summary of the above