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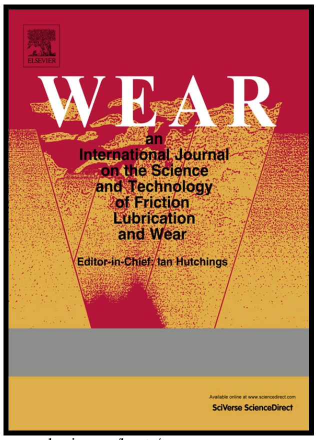

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Mechanical properties and fatigue behaviour of railway wheel steels as influenced by mechanical and thermal loadings

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ABSTRACT

During the operation of trains, high thermal loads are evolved because of recurring acceleration, braking, curving and occasional slippage. Furthermore, since long-term block braking may heat the wheel rim to over 500°C, it is relevant to examine the high temperature performance of wheel material as well as the decrease in strength after thermal exposure. This work concerns the elevated temperature low cycle fatigue behaviour, and the deterioration of microstructure caused by pre-deformation and heat treatment. The materials examined are two similar medium carbon steels UIC ER7T and ER8T (~0.55 wt.% C), heat treated in regular wheel production to a near pearlitic microstructure with some 5–10% pro-eutectoid ferrite in the wheel tread surface. For the study of microstructure deterioration, specimens were extracted from virgin wheels and pre-strained both monotonically to 6.5% strain and cyclically, to imitate plastic deformation inherent in the wheel tread surface. Both un-deformed and pre-strained materials were heat treated from 250°C to 650°C for various time durations, and thereafter the change in room temperature hardness was measured and the microstructural degradation was analysed. Hardening due to strain ageing was observed around 300°C while microstructure degradation caused softening at higher temperatures. Spheroidization of the pearlite started to become visible at 450°C for the un-deformed material and at around 400°C for the pre-strained. The elevated temperature low cycle fatigue tests showed a similar increase in strength around 300°C due to dynamic strain ageing, and decreasing strength at higher temperatures due to increased thermal activation and microstructure degeneration. Hold times showed that viscous effects exist already at 250°C giving stress relaxation, but the influence of hold times on further cycling is small regarding stress-strain relations.

Keywords: Low cycle fatigue LCF; Hardness; Thermal effects; Steel; Railway wheels

1. INTRODUCTION

The railway industry has always relied on steel material for the manufacturing of wheels and rails. Medium carbon steels with around 0.55 wt.% carbon are commonly used for the manufacturing of forged railway wheels, because they combine good strength and wear properties. Two grades are very common on trains in Europe; the ER7T grade is the dominating grade on freight trains and on many passenger coaches, while the ER8T grade with slightly higher carbon content is often used for passenger trains with driven wheels, so called EMUs (Electric multiple units) [1]. During the operation of these trains, high thermal loads are evolved because of recurring acceleration, braking, curving and slippage. These can reach over 500°C in the wheel tread during freight operation as it has been reported in literature [2] which can be problematic for the material's microstructural integrity. Control of material property degradation in wheels is an important topic for guiding maintenance as well as ensuring safety of railways, since it will allow for a more accurate prediction of material wear and lifetime.

In production, after forging and rolling, wheels are rim chilled: a heat treatment yielding a microstructure consisting of mostly pearlite with some 5-10 vol. % pro-eutectoid ferrite just below the wheel tread [3]. The main issue that arises during this operation is that exposure to elevated temperatures yields spheroidization of the pearlitic structure, which makes the material softer. Another factor that affects the spheroidization is the plastic deformation happening during train operations. After the material has experienced plastic deformation, it becomes even more prone to spheroidization of the lamellas during exposure to high temperatures. It is thus relevant to understand the high temperature performance of wheel material and evaluate the decrease in strength after thermal exposure as well as the decrease in fatigue life.