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Multi-scale description of a scenario of progressive shear-induced white etching layer (WEL) formation in the wheel-rail contact

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The formation of WEL, a very hard and brittle phase on the rail surface, is associated to a progressive transformation of the rail surface due to the cumulative passage of trains. Thanks to multi-scale observations, five successive stages of evolution are then proposed to characterize the WEL formation. Shear is assumed to be one of the driving forces in the formation of WEL. Shear tests using hat-shaped specimen and a Gleeble 3800 thermo-mechanical testing machine confirmed the role of shear in the formation of WEL, which has been reproduced successfully for temperatures below 300°C.

Keywords (from 3 to 5 max): White Etching Layer (WEL), wheel-rail contact, Shear test, Hat-shaped specimen, multiscale approach

1. Introduction

Due to the increase in rail traffic, railway networks are facing the presence of many rolling contact fatigue defects. With the accumulation of trains and according to the contact conditions after each train passage, the rail undergoes severe plastic deformation leading either to the fracture of the rail or to a solid-solid phase transformation close to the surface, called the "White Etching Layers" (WEL). Due to its brittleness and the incompatibilities with the parent phase, the WEL leads also to the rupture of the rails [1]. A scenario of progressive shear-induced-transformation from an initial pearlitic structure to a WEL structure is proposed.

2. Methods

The first step was the characterization of the microstructural gradient of worn rails in the presence of WELs. Coupling multiscale characterization techniques (OM and EBSD measurements) allowed the determination of several microstructural indicators such as grain size, grain distortion, grain boundary disorientation and deformation. Using these indicators, a scenario for gradual WEL formation is proposed. The latter can be divided into five successive stages of transformation named as:

- *Pearlitic structure as-received*
- *Fibering without fragmentation*
- *Fibering with fragmentation*
- *Nanostructuring without fibering*
- *Final state of WEL*

In this scenario, shear is assumed to be one of the driving forces in the WEL formation. The effect of possible temperature rises above the austenitization temperature does not contradict this scenario. The kinetics of WEL formation would then be catalyzed.

To validate this WEL formation mechanism, a test campaign of cyclic shear test is then conducted. A Gleeble 3800 thermo-mechanical testing machine is then used to reproduce the thermomechanical loading in the wheel rail contact. Hat-shaped specimens are used to simulate the shear stress within the material [2]. During the test campaign, monotonic and cyclic cases were carried out for three temperatures (20°C, 200°C and 400°C), and several amplitudes of applied force.

3. Discussion

These experiments have reproduced successfully similar microstructural evolutions as in the worn rail. For the first time, WEL patches were created mechanically, without any contact such as in conventional test benches. Thus, it confirms the role of the shear in the WEL formation.

The second striking result is a high temperature sensitivity of the material in its mechanical behaviour (fatigue or monotonic loading), its microstructural evolutions and its mechanisms of failure. The preliminary results show that the temperature would not favor the formation of WEL above 300°C.

This study is then a promising way to reproduce WEL in laboratory in order to predict its formation conditions. It would be a strong tool in the steel-making industry to develop new steel grades and increase the safety of current and future railway networks.

4. References

[1] A. Kumar, G. Agarwal, R. Petrov, S. Goto, J. Sietsma, et M. Herbig, « Microstructural evolution of white and brown etching layers in pearlitic rail steels », Acta Materialia, vol. 171, p. 48-64, 2019, doi: 10.1016/j.actamat.2019.04.012.

[2] J. F. C. Lins, H. R. Z. Sandim, H.-J. Kestenbach, D. Raabe, et K. S. Vecchio, « A microstructural investigation of adiabatic shear bands in an interstitial free steel », Materials Science and Engineering: A, vol. 457, no 1-2, p. 205-218, 2007, doi: 10.1016/j.msea.2006.12.019.

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