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Reproduction of mechanically induced white etching layer (WEL) using a test rig representative of wheel-rail contact conditions: from experimental to numerical simulations

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The formation of WEL, a very hard and brittle phase on the rail surface, is associated to severe thermo-mechanical contact conditions induced by the cumulative passage of trains. A test bench representative of the wheel-rail contact conditions has been developed and has successfully reproduced mechanically WEL areas. In order to determine the exact mechanical stress state leading to the WEL formation, 3D finite element simulations of the different test conditions were conducted. Thanks to the confrontation of numerical and experimental results, a thermomechanical model of WEL formation has been validated and accurately identified.

Keywords (from 3 to 5 max): White Etching Layer (WEL), wheel-rail contact, thermo-mechanical modelling, finite element analysis

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. In any case, the occurrence of those defects is due to a repetitive thermo-mechanical loading that will induce irreversible transformations in the material. Determining the thermomechanical conditions leading to the WEL formation is therefore necessary to predict the possible failure of the rails. A methodology coupling numerical simulations and experimental results is then presented to determine those conditions.

2. Methods

The first results from a previous test campaign highlighted the mechanical formation of WEL under the most extreme shear contact conditions [1]. These previous experiments confirmed the role of shear in the formation of WEL. A new test campaign was then carried out by amplifying the contact conditions to theoretically obtain larger WEL zones and to catalyze the WEL formation kinetics. In those experiments, the temperature rises were only a few degrees. Thus, this test bench allows to determine pressure and shear stress conditions leading to the WEL formation.

Simultaneously, a thermomechanical model of WEL formation was developed [2] assuming a coupling between the hydrostatic pressure, the shear stress and the temperature. This model allows to predict the conditions and the kinetics for the WEL formation. Moreover, an internal variable linked to the density change is introduced to follow “numerically” the different steps of transformation of the microstructure until the WEL formation.

Finally, 3D finite element simulations representing the different contact conditions of the experiments were performed using the thermomechanical model. The aim is then to determine the mechanical stress state of the elements at the contact surface.

3. Discussion

The numerical simulations showed a very good correlation with the experimental observations both in terms of the size of the transformed zone and for the kinetics of the WEL formation. Thus, the coupling between the shear stress and the pressure is confirmed and the thermo-mechanical model can be identified.

This methodology combining experimental results and numerical simulations is a strong tool to determine exactly the mechanical stress state at the contact surface for different experimental contact conditions (creepage, contact pressure). The thermomechanical conditions leading to the formation of WEL can therefore be accurately determined.

4. References

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