Role of white etching layer on rail squat formation

S. Simon [a b #], A. Saulot [a], X. Quost [b], Y. Berthier [a]

[a] *Laboratoire de Mécanique des Contacts et des Structures*
LaMCoS, INSA-Lyon, CNRS UMR5259, F69621, France
[b] *Régie Autonome des Transports Parisiens (RATP)*
50, rue Roger Salengro, 94724 Fontenay-Sous-Bois Cedex, France
Corresponding author : samuel.simon@insa-lyon.fr

1. Introduction

The well-developed form of squats is identified [1] as a light depression and widening of the rail tread along with a blackish spot and two V-shape cracks.

Squats have recently become recognized as one of the major rolling contact fatigue defects in modern railway networks. Consequently, many studies have been performed to understand the mechanisms by which squats are initiated, but this initiation is still controversial [2-4].

2. Initiation scenario

In a previous work, an initiation scenario was deduced from tribological observations of incipient squats samples: Contact conditions vary according to the contact location along the transversal profile (in particular in terms of value and direction of the shear stress). Thus step by step, the microstructure of the bulk material changes in a single and specific way for each longitudinal strip: distinct accumulative plastic deformations take place in terms of value and direction. After a certain number of cycles, the specific tribological responses on each strip generate microstructures whose mechanical properties become radically incompatible and thus an aera of differential tribological transformations uprises. The border between those strips develops into a weak area on the surface and squat-type crack can emerge due to excess inhomogeneity or isolated shock. In this study, two tests have been carried out in order to better understand contact conditions in squat area and to validate the initiation scenario against the reality of traffic.

3. Experimental details

On one hand an instrumented passenger train ran on the squats areas of the Parisian railway network. The instrumentation consisted of three main features: wheels plates were equipped with strain gauges to measure stresses in the three directions, a laser display system made possible an accurate location of rail/wheel contact and the displacement in the suspensions were monitored. The train ran under various loading, speed and accelerations conditions in squat areas.

On the other hand a test site with a lot of severe squats was spotted and replaced at the end of 2009 with rails made up of four different steel grades (three pearlitic and one bainitic structures) and various initial grinding conditions. Surface modifications of these rails were carefully followed for several years. Moreover after the outbreak of tribological transformation of surface, a part of the rails has been removed and observed by scanning electron microscopy.

4. Results

These tests provided validation elements for each step of the supposed damage mechanism. Firstly measured data with the instrumented train allowed us to know the influence of different factors in the initiation mechanism. Our interest was focused in particular on three variables: value of the longitudinal force, local sliding and wheel/rail relative position. These values reflect the local contact conditions and consequently the formation of longitudinal strips with different distorted microstructures on the tread became clearer. The evolution of these local conditions was also linked to macroscopic parameters such as speed, loading, dynamic behaviour.

Secondly the monitoring of the four steel grades allowed us to verify the impact of traffic on the rail microstructure during a long time scale. Thereby we have monitored regularly the profiles adaptation, the local increases of hardness and the outbreaks of tribological transformations of surface. Changes of different grades in the same conditions made easier the study of competition between wear and fatigue. Some grades have tended to be more sensitive to our initiation mechanism.

Results from these tests provide new elements to better understand the initiation mechanism of squat defect from microscopic to macroscopic scales.

5. References

[1] UIC Code 712, Rails defects, 4th edition, January 2002
[2] Z. Li, X. Zhao, C. Esveld, R. Dollevoet and M. Molodova, An investigation into the causes of squats – Correlation analysis and numerical modelling, Wear 265 (2008) 1349-1355
[3] M. Steenbergen, R. Dollevoet, On the mechanism of squat formation on train rails – Part I: Origination, International journal of Fatigue Vol47, February 2013, Pages 361–372
[4] S. Pal, C. Valente, W. Daniel, M. Farjoo, Metallurgical and physical understanding of rail squat initiation and propagation, Wear 284-285 (2012) 30-42
[5] S. Simon, A. Saulot , C. Dayot, X. Quost , Y. Berthier, Tribological characterization of rail squat defects, Wear 297 (2013) 926-942