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3D FE Modelling of Wheel-Rail Frictional Rolling Contact in Elasto-Plasticity for Investigation on Short Pitch Corrugation

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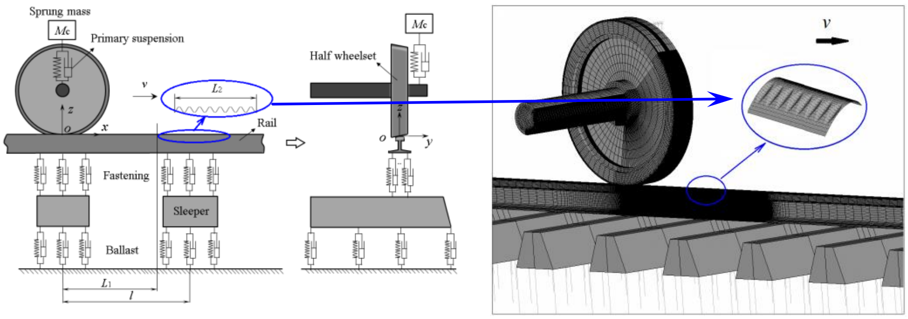
In the presence of short pitch corrugation (hereinafter referred to as corrugation for short) on the wheel-rail contact surface, high frequency wheel-rail contact force is induced together with high level of vibrations and noise. Corrugation has for many years been a problem for worldwide railway networks. It is commonly seen in straight tracks or tracks with gentle curves. It can be found on all kinds of railways: conventional and high speed, main line and metro/light rail. The induced dynamic wheel-rail contact force accelerates the degradation of the components of the wheel-track system, shortening their service life. The resulting noise, which is also known as “roaring rail”, is an annoyance to residents nearby. The damage mechanisms of the corrugation are wear and plastic deformation [1]. However, there is not yet a theory which can fully give an explanation of the initiation and growth mechanisms of the corrugation. And no parameters in the wheel-track system have been identified which can help to avoid or mitigate this problem. So far, the only effective solution to the corrugation is regularly grinding the rail surface, which increases the operation costs and reduces the availability of the networks.

In previous research, wear, treated to be proportional to the frictional work at the wheel-rail contact, has usually been considered and analysed as the damage mechanism [2−4]. However, due to the simplifications made, especially with the treatment of the frictional rolling contact in their models, different or even conflicting results and conclusions have been obtained [2, 4]. Further, plastic deformation as a damage mechanism has seldom been considered. There is a necessity for a new modelling approach, which can consider both the damage mechanisms of wear and plastic deformation, include all the potentially important elements, and reasonably treat the wheel-rail contact problem.

Li et al [5] developed a three dimensional (3-D) finite element (FE) model for investigation on the squats problem. The model was found capable to predict the corrugation-like wave patterns following the squat [5, 6]. Therefore, it was adopted to study the corrugation in [7]; the material was treated as being elastic; wear was considered to be responsible for the initiation and growth of the corrugation. The results show that for rails without and with the corrugation of different severity, there is roughly a constant phase difference between the corrugation and the wheel-rail vertical dynamic contact force; this shows that in the model the conditions for initiation and growth of the corrugation can be treated consistently, an critically important prerequisite for modelling of the corrugation.

In this paper, the model is further developed to include the elasto-plastic material property of the rail. Plastic deformation, as a damage mechanism for the corrugation will be investigated. The 3-D transient FE model of vehicle-track interaction with wheel-rail frictional rolling contact is shown in Figure 1 (a). To simulate the influence of the corrugation, a total of 8 waves of corrugation are applied in the rail surface (Figure 1 (b)).

It is expected that through the comparison of the distributions of wear and deformation along the corrugation, the roles of both wear and plastic deformation on the initiation and growth of corrugation can be identified.



(a) (b)

Figure 1. The FE model of the wheel-track interaction: (a) A schematic diagram, (b) The mesh

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