Journal of Sound and Vibration 410 (2017) 318–329

Contents lists available at ScienceDirect

Journal of Sound and Vibration

journal homepage: www.elsevier.com/locate/jsvi

Simulation of vertical dynamic vehicle–track interaction in a railway crossing using Green's functions

X. Li *, P.T. Torstensson, J.C.O. Nielsen

Department of Applied Mechanics/CHARMEC, Chalmers University of Technology, SE-412 96, Gothenburg, Sweden

ARTICLE INFO

Article history:
Received 29 November 2016
Revised 11 August 2017
Accepted 16 August 2017
Available online XXX

Keywords:
Railway crossing
Vehicle–track interaction
Impact load
Green's functions

ABSTRACT

Vertical dynamic vehicle–track interaction in the through route of a railway crossing is simulated in the time domain based on a Green's function approach for the track in combination with an implementation of Kalker's variational method to solve the non-Hertzian, and potentially multiple, wheel–rail contact. The track is described by a linear, three-dimensional and non-periodic finite element model of a railway turnout accounting for the variations in rail cross-sections and sleeper lengths, and including baseplates and resilient elements. To reduce calculation time due to the complexity of the track model, involving a large number of elements and degrees-of-freedom, a complex-valued modal superposition with a truncated mode set is applied before the impulse response functions are calculated at various positions along the crossing panel. The variation in three-dimensional contact geometry of the crossing and wheel is described by linear surface elements. In each time step of the contact detection algorithm, the lateral position of the wheelset centre is prescribed but the contact positions on wheel and rail are not, allowing for an accurate prediction of the wheel transition between wing rail and crossing rail. The method is demonstrated by calculating the wheel–rail impact load and contact stress distribution for a nominal S1002 wheel profile passing over a nominal crossing geometry. A parameter study is performed to determine the influence of vehicle speed, rail pad stiffness, lateral wheelset position and wheel profile on the impact load generated at the crossing. It is shown that the magnitude of the impact load is more influenced the wheel–rail contact geometry than by the selection of rail pad stiffness.

1. Introduction

Turnouts (switches and crossings, S&C) are critical components of a railway track requiring regular maintenance and generating high life cycle costs. Main drivers for the high maintenance costs are needs to repair and replace switch rails and crossing rails due to plastic deformation, wear and rolling contact fatigue.

A wheel passing over the crossing in the facing move (from the switch panel towards the crossing panel) will first make contact with the outwards deviating wing rail, see Fig. 1(a). The wheel–rail contact then moves towards the field side of the wheel profile. For a typical conical wheel profile, the rolling radius decreases and the wheel moves downwards unless the wing rail is elevated. When the wheel reaches and makes contact with the crossing nose, the contact load is transferred from the wing rail to the crossing nose. The rolling radius will then increase as the new contact is closer to the wheel flange. The dynamic vehicle–track interaction typically results in an impact load on the crossing nose as the downward motion of the vertical wheel

* Corresponding author.
E-mail address: xin.li@chalmers.se (X. Li).

http://dx.doi.org/10.1016/j.jsv.2017.08.037
0022-460X/© 2017 Published by Elsevier Ltd.

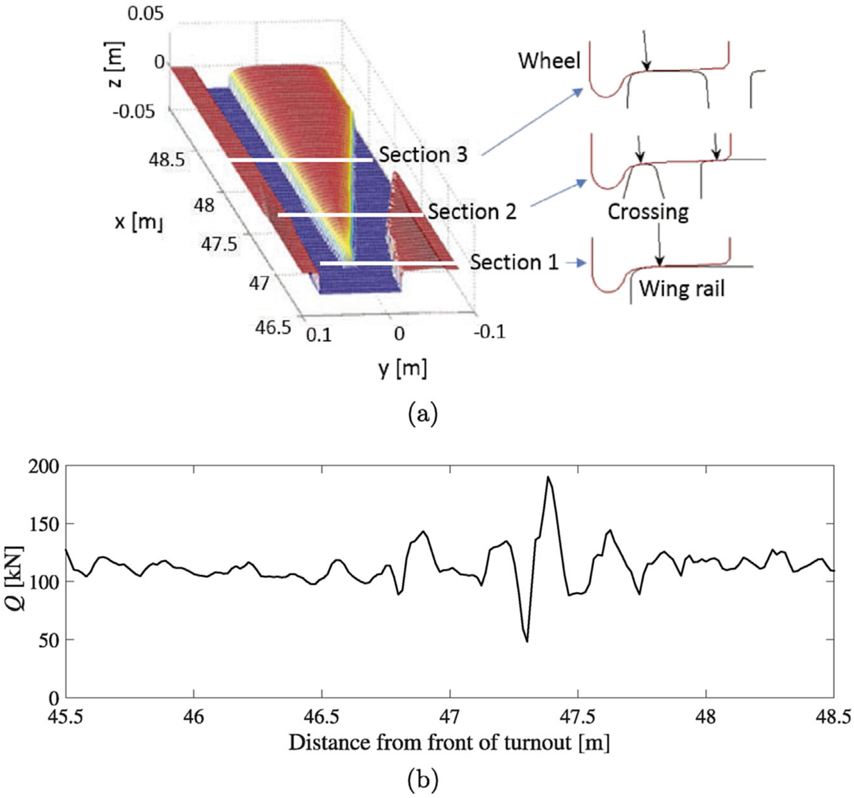

Fig. 1. (a) Rail configuration at crossing illustrating parts of two wing rails and one crossing nose. The crossing transition takes place at around 47.2 m (the theoretical crossing point, TCP) from front of turnout. From Ref. [2]. (b) Measured vertical wheel–rail contact force during a crossing transition. The total vertical force on the wheel was measured by strain gauges on the wheel disc. Traffic in facing move of the through route at 70 km/h. From Ref. [6].

trajectory is reversed and the wheel is accelerated upwards by the crossing nose, see Fig. 1(b), where the theoretical crossing point (TCP) is at 47.2 m from the front of the turnout [1]. Impact loads with high magnitudes, as caused by non-optimal wheel–rail contact geometry in the transition zone, may lead to severe plastic deformation of the rails and to subsurface-initiated rolling contact fatigue resulting in breakouts of material due to the merging of cracks, see Fig. 2. Particularly severe impact loads are generated if wheel and rail profiles are not correctly maintained as will be demonstrated by the model presented in this paper.

The influence of the rail profile and track stiffness on the impact load, wear and rolling contact fatigue in a crossing panel has been studied previously, see Refs. [2–4]. In Refs. [2] and [3], a so-called moving track model was employed to simulate

Fig. 2. Examples of damage in a railway crossing: (a) plastic deformation of the wing rail and (b) rolling contact fatigue of the crossing nose (spalling). Photos published with permission from (a) voestalpine VAE GmbH and (b) Jay Jaiswal, private communication.