Implementation of a non-Hertzian Contact Model for Railway Dynamics

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Multibody dynamics allows the simulation of a railway vehicle negotiating a railway track with realistic operation conditions. The vehicle-track interaction, i.e., the forces developed in the wheel-rail interface, is represented by a wheel-rail contact model, which plays a key role in such simulations. Although different models have been proposed [1], this is still an active topic of research since more accurate and reliable models are demanded to solve industrial problems, as for example the minimization of the maintenance costs related to wear or rolling contact fatigue.

The selection of a wheel-rail contact model requires a trade-off between accuracy and computational efficiency. This selection depends on the purpose of the study, for example, to perform a wear study the contact model must represent accurately the stress distribution in the contact region [2], however, for the vehicle dynamics simulation, only the resultant force applied in the wheel is required [3].

The resolution of the wheel-rail contact in the context of a multibody simulation can be divided into three subproblems. (i) the contact detection between the wheel and rail is assessed being identifying the contact kinematics, i.e., the contact points and the creepages, namely, the longitudinal creepage, v_x, the lateral creepage, v_y and the spin creepage, φ; (ii) the normal contact problem is solved, being defined the normal pressure distribution which leads to a normal force that results from the integration of the normal pressure over the contact area; (iii) the tangential contact problem is solved by determining the tangential pressure distribution and hence the resulting creep forces.

The main purpose of this work is to perform reliable simulations for wear studies, in which the focus is the proper implementation of a non-Hertzian wheel-rail contact model in a multibody software implemented in MATLAB. Here, the wheel and rail profiles are considered rigid to solve the contact detection problem, namely, to identify the location of contact points of higher penetration, since an elastic approach is utilized. To reach this goal, the wheel and rail profiles are parameterized with two parameters each, namely, s_p and u_p, being the subscript p related to the wheel if p=w or related to the rail if p=r. Thus, a potential contact point is obtained determining a set of four parameters, namely s_w, u_w, s_r and u_r, that satisfies a system of four non-linear equations, which relate the relative orientations of the vectors that define the contacting surfaces [4]. The parameterization of the wheel and rail profiles and the contact detection approach is schematically depicted in Fig. 1. For the evaluation of the normal force, the contact patch is defined by strips as shown in Fig. 2 (a). For each strip, the parabolic pressure distribution proposed by Kik and Piotrowski [5] is considered and hence the normal contact problem is solved. In turn, to obtain the tangential forces, an improved version of the Kalker Book of Table for Non-Hertzian contact (KBTNH) [6] is used, for which not only the creepages are required but also the contact patch is approximated by a simple double-elliptical contact region (SDEC) to obtain its geometric parameters a, b and y_0. Fig. 2 (b) represents the approach used to solve the tangential problem.

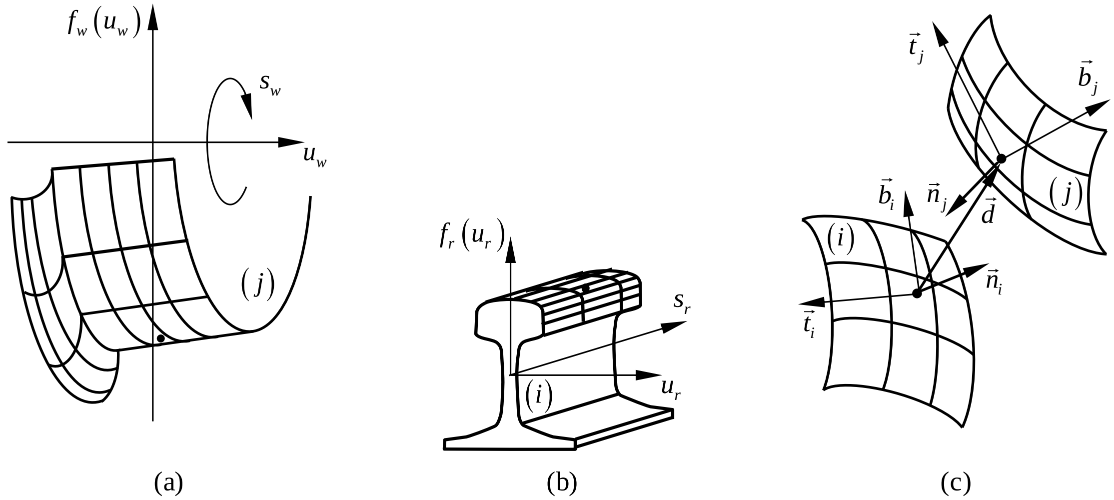

Fig. 1: Parameterization of the (a) wheel and (b) rail and (c) contact detection between surfaces

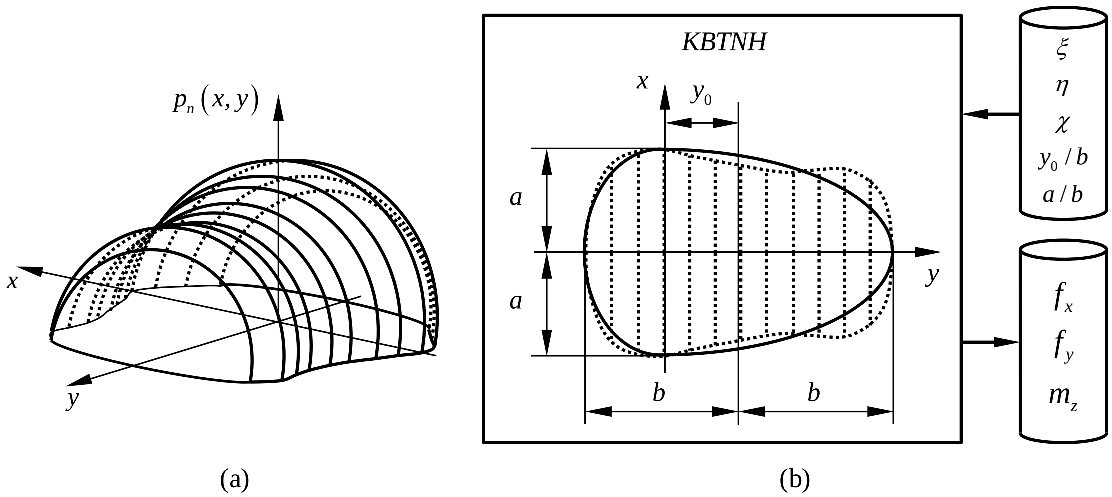

Fig. 2: (a) Normal pressure distribution for an arbitrary contact patch [5] and (b) creepage forces obtained from the Kalker Book of Tables for Non-Hertzian (KBTNH) contact patches [6]

A case study involving the operation of a railway vehicle in a realistic track is presented here to demonstrate the developments proposed in this work. In the process, a comparison between the non-Hertzian contact model presented in this work and the Hertzian contact model implemented by Pombo [4] is made to assess the impact of the wheel-rail contact model on the vehicle dynamics and computational effort.

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