Comparison of Computational Efficiency Between Constraint-based Contact Methods in the Description of Wheel-rail Contacts

Xinxin Yu[1], Javier F. Aceituno[2], Emil Kurvinen[1], Marko K. Matikainen[1], Pasi Korkealaakso[3], Asko Rouvinen[3], Dezhi Jiang[1], José L. Escalona[4], Aki Mikkola[1]

[1] Mechanical Engineering
LUT University (Finland)
[xinxin.yu, emil.kurvinen, marko.matikainen, aki.mikkola]
@lut.fi, dezhi.jiang@student.lut.fi

[2] Mechanical and Mining Engineering
University of Jaén (Spain)
jaceitun@ujaen.es

[3]Mevea Ltd. (Finland)
[pasi.korkealaakso, asko.rouvinen]@mevea.com

[4]Mechanical and Manufacturing Engineering
University of Seville (Spain)
escalona@us.es

A railway vehicle is a complex mechanical system which consists of several bodies, wheel-rail contacts, and complicated suspension elements. In real-time simulation, the solver efficiency is of great importance [1]. In this work, the Knife-edge Equivalent Contact (KEC) constraint method and lookup table method are compared in terms of computational efficiency and accuracy. To complete the railway vehicle model, both contact methods are implemented into the multibody model of a benchmark railway vehicle [2]. Four different integrators of which two are fixed step size integrators: explicit Runge-Kutta method (RK4) and implicit Adam-Bashforth-Moulton method (ABM), and two with variable step size, Matlab built-in function integrators explicit $ode45$ and implicit $ode15s$, are applied for the numerical solution of dynamic problems and to study numerical performance of the two contact description methods from the computational efficiency and accuracy perspective.

1 Description of the KEC-method

KEC-method [3] is an online constraint method, in which the wheel rail profile combination is established by an equivalent wheel profile in contact with an infinitely narrow rail that results in the same space of allowable relative motion. This equivalent profile combination produces the same wheel/rail contact kinematics as the real wheel/rail profiles, as shown in Fig. 1. In Fig. 1 (a), the contact points for a set of discrete values of the wheelset lateral displacement are located at the wheel/rail profiles. Accordingly, the corresponding contact points can be found on the KEC-equivalent profiles, as depicted in Fig. 1 (b). To this end, the exact position of the contact points can be determined from the online solution of KEC constraints. One advantage of the KEC-method, is that contact forces on the tread and the flange can be treated equally as reaction forces. A regularisation of the tread-flange transition is adopted to simultaneously account for tread and flange contacts using constraints.

2 Description of the lookup table approach

Contact lookup table method is an offline constraint method, in which the contact detection is processed in a preprocessing stage and the solution is stored in a lookup table. Later in the dynamic simulations, the contact points are obtained by interpolating between the stored data. In this work, a constraint contact lookup table approach that accounts for track irregularities with two entries, the lateral displacement and the track gauge variation, is used [5]. A hybrid method is adopted to compute normal

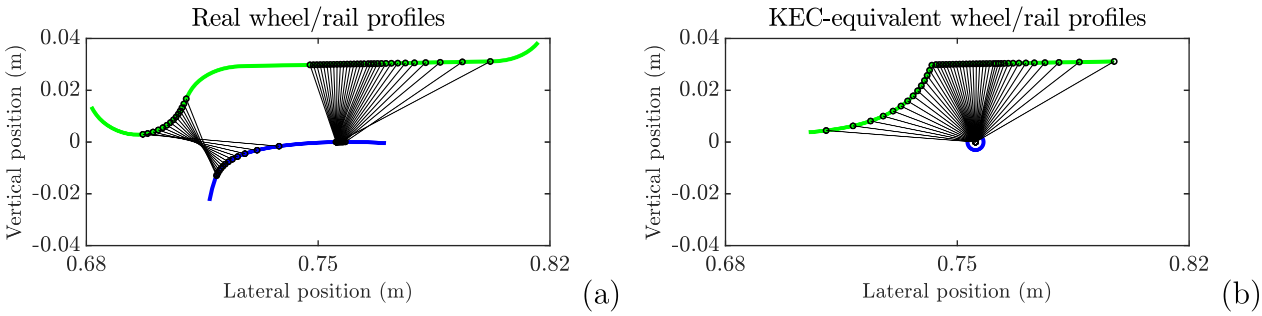

Figure 1. (a): Contact points on real wheel/rail profiles and (b) contact point on KEC-equivalent wheel/rail profile. Green solid curve represents the wheel profile and blue represents the rail profile.

contact forces at tread and flange. The normal contact forces in the tread are computed as reaction forces associated with contact constraints, while the normal contact force for the flange is computed using a Hertzian model, based on the interpenetration and interpenetration rate. The compliant force model used for flange normal contact is given as

$$f_n = K_{hertz}\delta^{1.5} + C_{damp}\dot{\delta}, \tag{1}$$

where K_{hertz} and C_{damp} are Hertzian contact stiffness and damping coefficients, δ and $\dot{\delta}$ are the wheel-rail penetration and its rate at the flange contact. It is noted that this Hertzian contact stiffness K_{hertz} will control the simulations using the lookup table method [4]. In this work, the computational efficiency and accuracy of the lookup table method with different flange contact stiffness are compared when using different integration methods.

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