Simplification of the Wheel-Rail Contact Constraints Using the Knife-Edge Contact Approach

José L. Escalona[1], Javier F. Aceintuno[2], Pedro Urda[3] and Sergio Muñoz[3]

[1] *Department of Engineering, Aarhus University, escalona@eng.au.dk*
[2] *Linares School of Engineering, University of Jaén, jaceitun@ujaen.es*
[3] *School of Engineering, University of Sevilla, {purda,sergiomunoz}@us.es*

This work presents a method to simplify the wheel-rail contact constraints that appear in railway multibody simulations. The relative motion of two rigid bodies with smooth 3D surfaces in contact is reduced by one degree of freedom. However, simulation of the motion requires the use of 5 constraints (3 contact-point constraints and 2 parallel-tangent-planes constraints) and 4 surface parameters. These constraints are computationally very expensive. In addition, derivatives of the surfaces geometry up to the 3rd degree are needed. In practice, information of the surfaces geometry in that level of detail in not available. The method proposed in this work starts by finding equivalent wheel-rail profiles that, maintaining the same wheel-rail relative kinematics, simplifies the constraint equations. The rail cross-section is assumed infinitely narrow (like the edge of a knife) and a new wheel profile is found such that it preserves the relative motion. Neglecting the influence of the wheel yaw motion on the wheel-rail contact, the use of the equivalent profiles reduces the constraint equations from 5 to 2 (only contact point constraints) and the number of surface parameters (*curve-parameters* in this case) from 4 to 2. These new contraint equations are called KEC- (*knife-edge contact*) constraints. The level of simplification is such that the one-line solution of the KEC-constraint equations can compete in terms of efficiency with the use of contact lookup tables while maintaing similar accuracy. Figure 1 shows the real wheel-rail profiles used in this work and the equivalent KEC-profiles. Figure 2 shows the relative wheel-rail kinematics when using the original and the KEC-profiles. The plots show the vertical displacement and roll rotation of the wheelset as a function of the lateral displacement.

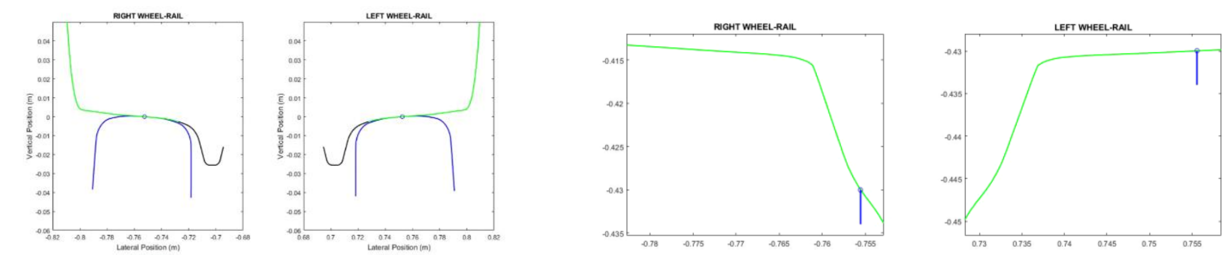

Fig. 1: Wheel-rail profiles in contact (left) and equivalent KEC-profiles

The used of the KEC-constraints have other interesting advantages when compared with the regular contact constraint equations. For those wheel-rail profiles that result in two-point contact scenario, the contact constraints cannot be used in both points simultaneously. The practical solution to this problem is either to use an elastic-contact approach or a hybrid approach in which the tread contact is treated with constraints and the flange contact is treated elastically [1]. In both cases the appearance of flange contact occurs as a result of an impact that has strong influence on the vehicle dynamics as well as on the numerical solution. The impact process requires a drastic solution of the time step. However, this impact process does not seem to occur in reality. In the method implemented in the railway simulation code Simpack, the wheel-rail contact follows the so-called *quasi-elastic approach* [2] that transforms the wheel-rail contact constraint in such a way that contact transition from tread to flange becomes continuous. Using the quasi-elastic approach the wheel-rail dynamics is smoothen but the two-point contact scenario is not described (contact forces are applied in a single point). The KEC-constraint approach developed in this work allows both the simulation of the two-point contact scenario and a smooth transition of the forces from the tread to the flange without using an elastic-contact approach. The resulting simulations can be more adequate to detect the derailment process while being computationally efficient.

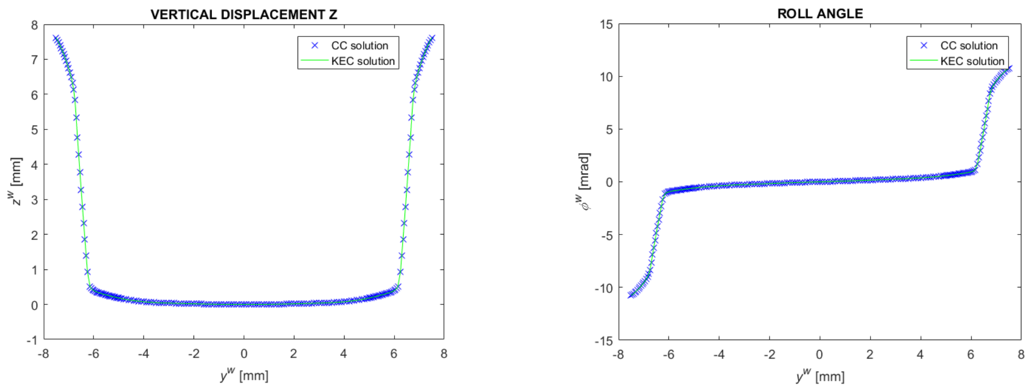

Fig. 2: Relative wheel-rail kinematics

The KEC-constraint method has been used for the simulation and safety analysis of Metro de Sevilla (metropolitan light train). The vehicle comprises 5 articulated cars and three bogies (two drive-bogies in the end cars and one trailer bogie in the middle car). Wheelsets have independently rotating wheels. The simulation assumes an 18 km-track with measured irregularities and a new forward-velocity profile. To simulate the forward motion of the vehicle a traction control algorithm has been implemented in the simulations. The objective of the simulation is the evaluation of the safety of the ride with this new forward-velocity profile. Figure 5 shows a top view of the train in an instant of the simulation and the normal and tangential contact forces obtained with the KEC-constraint method.

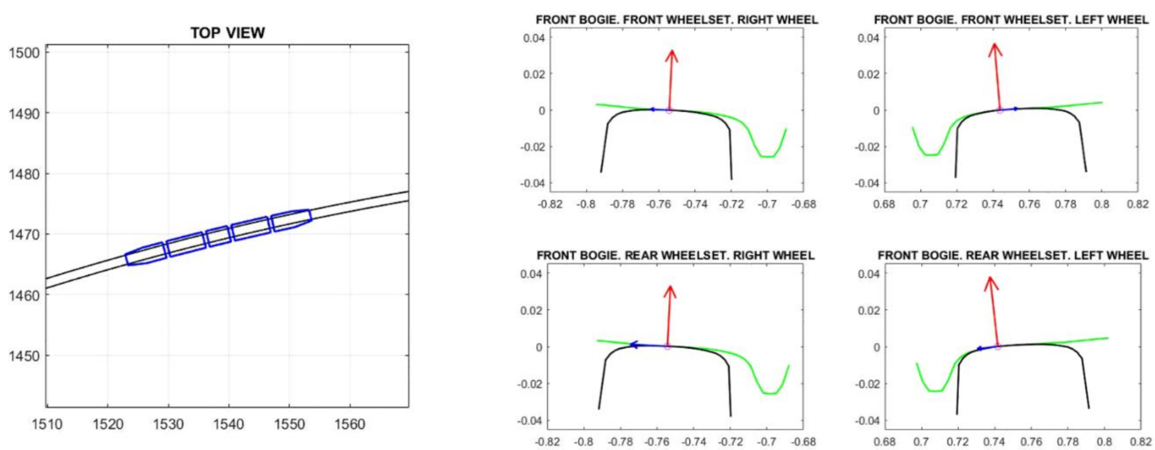

Fig. 3: Simulation of Metro de Sevilla. Top view of the train (left) and computed wheel-rail contact forces (right)

Acknowledgments

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