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An Efficient Constraint Contact Approach for the Calculation of Wheel-Rail Interaction with Worn Profiles

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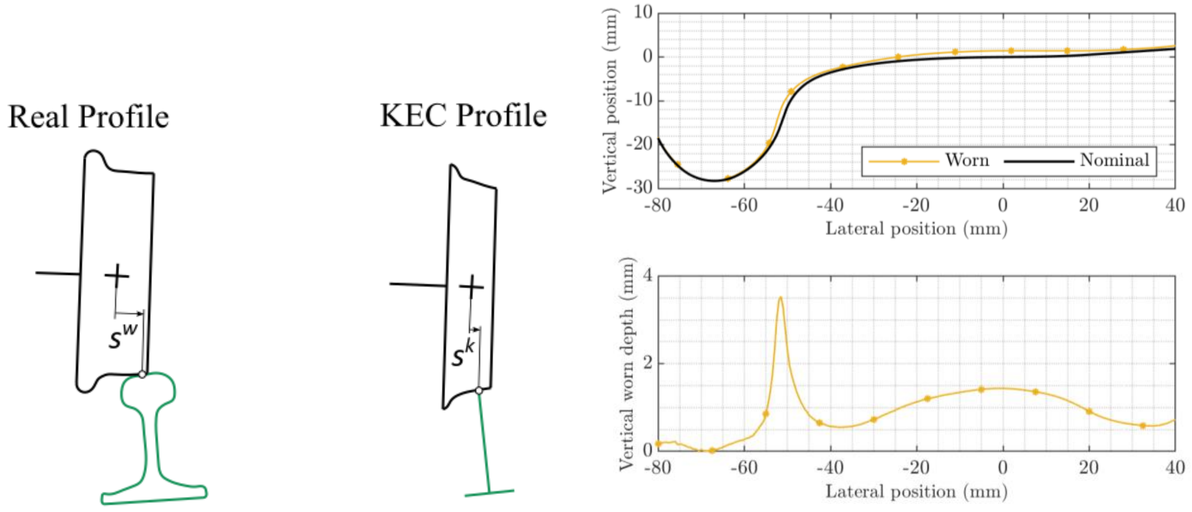
Abstract

The modelling of wheel-rail interaction plays a main role through the literature, due to its essential nature for analyzing the dynamic behavior of railway vehicles. In reality, the wheel and rail profiles under the train cannot be always nominal (new profile). Those wears at the wheel–rail interface and will result in multi-point contact, conformal contact, and irregular contact patches, making the dynamic analysis of the railway vehicles more complex. Hence, the development of efficient but accurate models that account for the wheel–rail contact solution with worn profiles is of great interest for railway industry and academy.

The constraint approach is developed to describe the contact between wheel and rail using a set of kinematic constraint equations, ensuring that both surfaces are in contact without penetration or separation. *Offline* contact detection is carried out and the resulting data is stored in a pre-processing stage. In the dynamic simulation, the contact location can be determined by interpolating the stored data, which greatly reduces the computation load. Over the years, a number of articles [1, 2, 3] have been published to develop the constraint approach for the calculation of wheel-rail interactions. However, this approach is not well popularized because only new wheel-rail profiles are applied, making it difficult to represent the real-life wheel-rail condition. The goal of this paper is to enhance the developed constraint approach, knife-edge contact (KEC) approach [2], for the estimation of the wheel-rail contact with worn profiles.

KEC method is an *online* constraint approach, where the real wheel/rail profile combination is established using an equivalent KEC profile in contact with an infinitely narrow rail, yielding the equivalent allowable relative motion. See Fig. 1(a). As shown in Fig. 1(a), surface parameters s^w is the wheel transverse surface parameter at the contact point and s^k is the corresponding KEC transverse surface parameter. Using KEC equivalent profile, the computational cost will be greatly reduced by solving simple KEC-constraints [2] instead of the more complicated contact constraint equations given in [1].

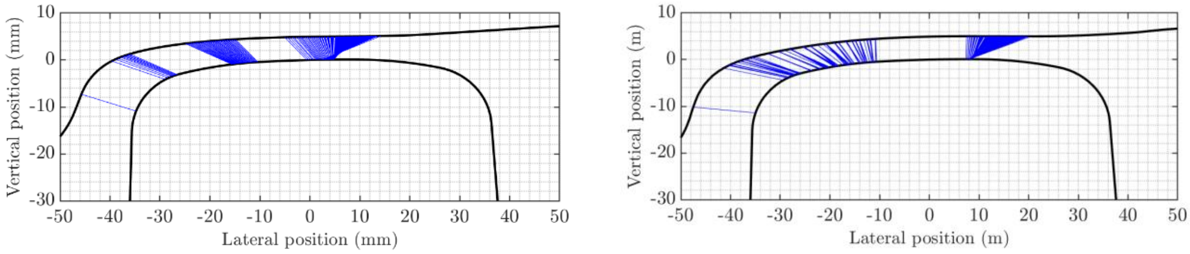


(a) (b)

Figure 1. (a) Real profile and KEC wheel profile (b) S1002 wheel profiles with nominal and worn shapes

To build the equivalent KEC profile in Fig. 1(a), the contact detection must be carried out in preprocessing stage. In this work, a general search scheme [4] is employed to handle the contact detection of arbitrary wheel-rail profiles, especially severely worn profiles. That is due to the detection approach in [4] being proved to be capable of searching for the locations of more than one contact between wheel-rail interface, which is superior to the conventional constraint approach used in [3].

The S1002 wheel with nominal and worn shapes are selected in this work. See Fig. 1(b). Figure 2 visualize the contact-point position between the real nominal UIC60 rail and S1002 wheel profiles. Comparing Fig. 2(a) to (b), one can observe that the nominal profile shows more jumps between contact points compared to the worn profile.



(a) (b)

Figure 2. (a) Nominal UIC60 rail and nominal S1002 wheel profiles, (b) nominal UIC60 rail and worn S1002 wheel profiles

The position of the contact point in the KEC-equivalent profile can be found by solving KEC-constraint equations [2]. Once the contact point on the KEC-equivalent profile s^k is determined, the location of the contact points s^w in the real wheel and rail profiles is easily obtained with using the relationship between KEC equivalent and real wheel profiles. Figure 3 shows this relationship for nominal and worn S1002 wheel profiles. It can be observed that for a certain value of the KEC transverse surface parameter s^{lk}, two simultaneous real transverse surface parameters can be found in the real profile s^{lw}. As shown in Fig. 3, polynomial curve fitting is applied to smooth the relationship curve and to improve the computation efficiency for the dynamic simulation with using the analytical expression.

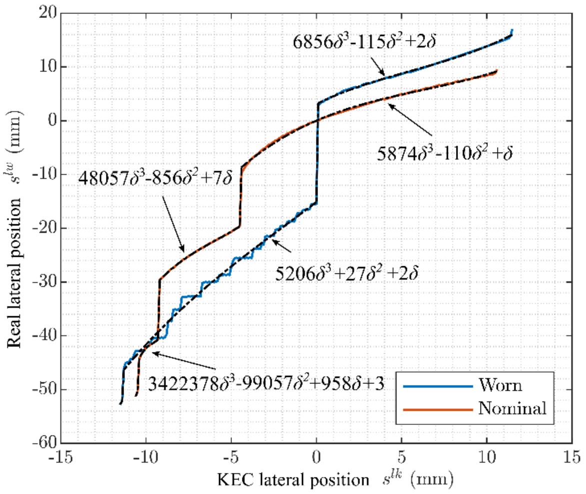


Figure 3. Relation between KEC equivalent and real wheel transverse surface parameter for nominal and worn S1002 profiles

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