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Efficient on-line calculation of the wheel-rail contact forces in multibody dynamics

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1 INTRODUCTION

The calculation of wheel-rail contact forces in the dynamic simulation of railroad vehicles [1] involves the following steps:

1. Location of the position of the contact points on the surfaces of the wheel and rail.
2. Calculation of the normal contact forces.
3. Calculation of the tangential (creep) forces and moments.

This paper deals with the first step that is probably the most time consuming. Therefore, an efficient method for the contact points location is essential for an efficient simulation. The methods that can be found in the literature can be classified according to three different criteria: wheel-rail assumed relative degrees of freedom (constraint method or elastic method), contact points selection (nodal points or continuous search), search domain (2D or 3D contact) and method of calculation (on-line calculations or look-up tables). The method proposed in this paper [2] is an elastic method with continuous search of contact points in a 3D domain that is designed to be used online. The method is accurate and numerically efficient.

2 WHEEL AND RAIL GEOMETRY

The method proposed for the search of the contact points requires the surfaces of the wheel and rail to be mathematically parametrized in such a way that the global position vector $\mathbf{r}^P$ of an arbitrary point P can be written according to the following formula:

$$\mathbf{r}^P = \mathbf{R}^l + \mathbf{A}^l \bar{\mathbf{u}}^P, \quad \bar{\mathbf{u}}^P = \bar{\mathbf{u}}^P\left(s_1^l, s_2^l\right), \tag{1}$$

where $l = w$ (wheel) or r (rail), $\mathbf{R}^l$ and $\mathbf{A}^l$ are the position of the origin and rotation matrix of the body frame of reference and $\bar{\mathbf{u}}^P$ is the position vector of the arbitrary point in the body frame that is a function of the surface parameters s_1^l and s_2^l. Figure 1 shows the surfaces parameters and frames of references used in this work for the wheel and rail.

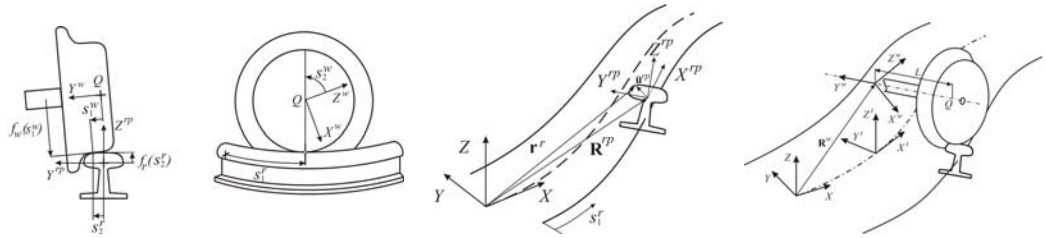


Figure 1. Wheel and rail geometry

3 SEARCH OF CONTACT POINTS

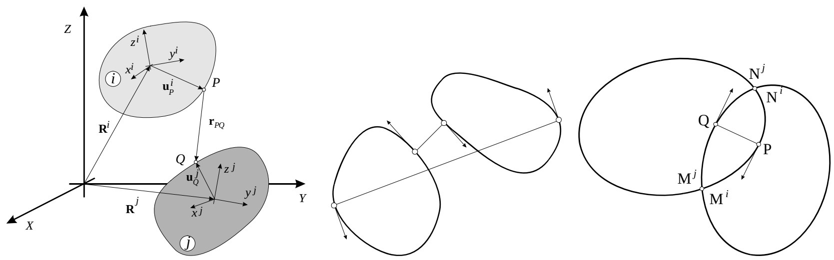
The method proposed for the search of contact points assumes that these points are at any instant a local maximum of the function that defines the distance between the surface of the two bodies (see points *P* and *Q* at fig. 2(c)). Therefore the contact points are obtained by optimizing the following function:

$$\mathbf{r}_{PQ} = \left(\mathbf{R}^j + \mathbf{A}^j \bar{\mathbf{u}}_Q^j\left(s_1^j, s_2^j\right)\right) - \left(\mathbf{R}^i + \mathbf{A}^i \bar{\mathbf{u}}_P^i\left(s_1^i, s_2^i\right)\right) \tag{2}$$

It can be demonstrated that the optimization leads to the following algebraic equations:

$$\mathbf{t}_l^{i^T} \mathbf{r}_{PQ} = 0, \quad \mathbf{t}_l^{i^T} \mathbf{n}^j = 0, \quad l = 1,2 \tag{3}$$

where $\mathbf{t}_l^i$ represent the tangents to the surface of body *i* and $\mathbf{n}^j$ the normal to body *j*. Equation (3) excludes other solutions of the optimization of the function distance that cannot be considered contact points as points M^i , M^j and N^i , N^j shown in fig. 2(c).



(a) (b) (c)

Figure 2. Optimization of the distance between two bodies

This method has the following advantages:

1. It can be used for tread and flange contact simultaneously.
2. It takes automatically into account lead and lag contact.
3. It allows separation while keeping track of the “candidates” contact points.
4. It can be used with track irregularities and flexible tracks.
5. Keeping a good initial guess for Eq. (3) the method requires few computations.

4 RESULTS

The method proposed can be used in numerical simulation as well as in stability analysis [3]. Figure 3 shows the eigenvalues associated with a wheelset on curved tracks as a function of the radius of the curve. The range of radius assumed is such that the wheel set shows flange contact in the outer wheel. As it can be seen (negative real parts of the eigenvalues), the wheelset, that is unstable on tangent tracks, becomes stable due to the flange contact.

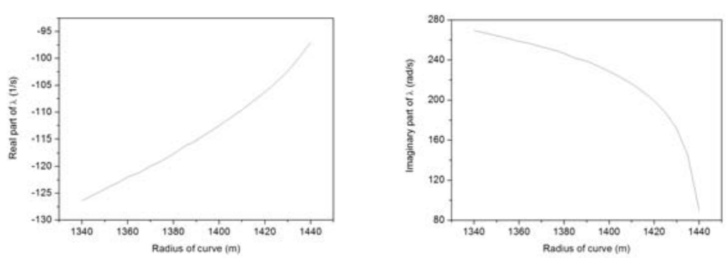


Figure 3. Eigenvalues of unsuspended wheelset on curved track

5 REFERENCES

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