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Train/track dynamic inertial interaction at medium and high speed

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Abstract

In the paper we prove that the dynamic simulation and investigation of a system of a vehicle moving on a track requires the assumption of a correct mechanical model. Travelling load that subjects rails can not be assumed as a set of massless forces. We must consider the inertia of parts of wheelsets that are inertially attached to rails. Simple test and complex simulations exhibit differences in results between classical massless loading by gravity loads resulting from a vehicle and the same set of forces with inertia partially transferred from vehicle wheels to rails. Unfortunately, numerical analysis of inertial loads are not implemented in commercial codes. Our results were compared with Adams software and measurements.

Keywords: moving inertial load, train/track interaction

1. Introduction

The interaction of the vehicle with the track in the complex system is fundamental. Unfortunately, the moving load problems are not widely implemented in commercial codes. Selected features, as for example vehicle body motion, wheel/rail or vehicle/rigid track interaction, influence of the wheel profile, can be investigated with well known codes Adams or Medyna. Unfortunately, the entire vehicle/track dynamics seems to exceed the scope of available present computer tools.

Several papers partly deal with the problem of dynamics of the vehicle–track system. Below we intend to demonstrate the dynamic analysis of vehicle–track system, with the influence of the inertia of the load. The problem is caused by the moving inertia, which increases instantaneously the track inertia (Figure 1).

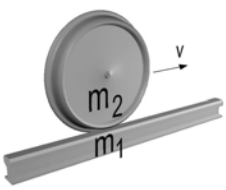

Figure 1: Moving mass of a wheel attached dynamically to the rail.

The usual way of the vehicle analysis is the elaboration of a spring–mass system or a more complex frame–plate structure, which influences the track as a set of contact massless forces. Their magnitudes are computed as reactions in wheel contact points or interactions of spring degrees of freedom with the elastic base. At low or medium speed range the lack of the moving inertia vertically attached with rails does not contribute a visible error. At higher speed range the influence of the part of the wheel mass being in permanent contact with the rail increases.

Figure 2 explains the difference in a moving load treatment. The third case corresponds with the real model with the part of the wheel mass attached to the beam. The increased mass of the part of the vibrating structure changes the dynamic response of the structure under the moving load. The theoretical analysis of the problem of an inertial load is presented in [3, 2]. Numerical analysis could not be previously performed. Existing examples of beam vibrations published in literature concern relatively low moving velocity and even in this case exhibit significant errors. At higher speed presented solutions differ significantly with accurate results. In the case of pure hyperbolic differential equations which describe a string or a bar vibrations, integrated numerically by the step-by-step schemes resulting solutions diverge. In a series of papers [1, 4, 5, 6, 7, 8] we explain how to derive elemental matrices that carry a moving mass particle and apply them to the finite element method or space-time finite element method.

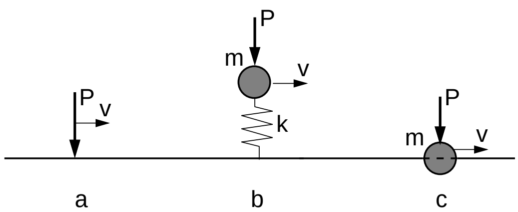

Figure 2: Types of the moving load: a) simple force, b) oscillator, c) inertial load.

2. Results

In our computations we use the geometric and material data as in [9]. The finite element is subjected at the intermediate point to the force with the inertia parameter, i.e., the concentrated mass. This force, usually placed in a numerical model at the right-hand side of the resulting system of algebraic equations, can be simply distributed over the neighbouring nodes. The bending moments in the case of a beam must appear at the finite element joints as well. The concentrated mass is incorporated directly into the left-hand side matrices. Their coefficients vary in each time step and this requires the solution of a system of equations at every time step. No iterations are required, unless unilateral contact is assumed. There are two advantages of such a solution: accurate and faster computations.

The track model is composed of plates, beams, grid or frame elements, and springs. A simple track structure can be considered in the same manner as a complex one. Let us look at the simplest classical track (Figure 3), built of sleepers as grid elements placed on an elastic Winkler foundation, springs which

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model elastic pads, and grid elements which describe rails, both straight and curved.

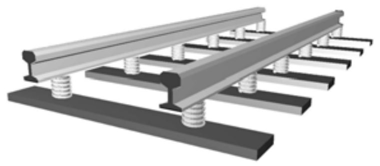

Figure 3: Substructures assumed in analysis.

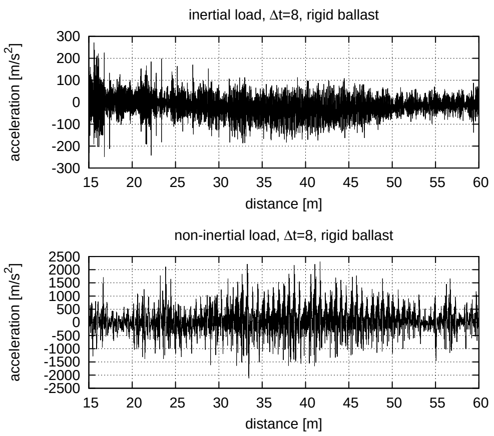

Figure 4: Vertical accelerations of the axle box at a speed of 290 km/h with the inertial and non-inertial loads assumed in the model.

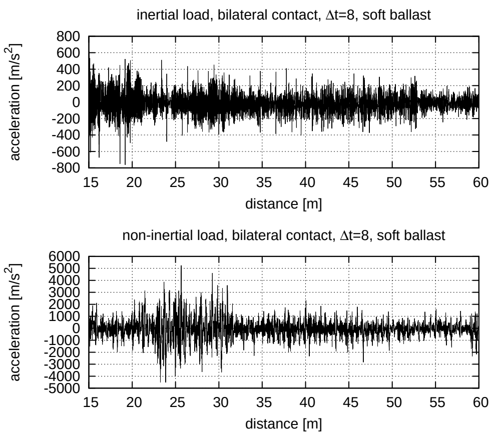

Figure 5: Vertical accelerations of the axle box at a speed of 290 km/h with the inertial and non-inertial loads assumed in the model with soft ballast.

In both Figures 4 and 5 in the case of a non-inertial load (lower diagrams) we can notice the strong influence of the sleepers. With an inertial load (upper plots), this influence is moderate and the dynamic response is more realistic.

We compare our results with the reference paper [9] (Figure 6). Both Figures 4 and 6, obtained for an inertial load, exhibit a similar range of accelerations of the axle box. The signal in Figure 6 shows a low frequency mode which is difficult to explain. The response of our numerical simulation has the same magnitude of accelerations and has more realistic higher frequency oscillations. The model analysis of the plotted signal is depicted in Figure 7.

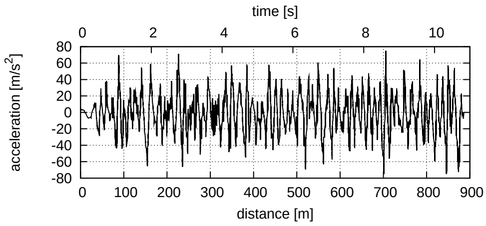

Figure 6: Accelerations of the axle box at a speed of 290 km/h taken from [9].

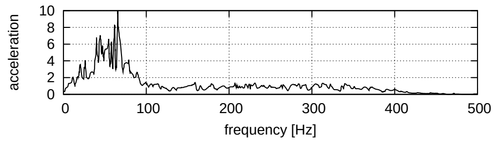

Figure 7: Modal analysis of the accelerations from Fig. 6 [9].

3. Conclusions

Inertial load significantly changes the dynamic response comparing with the massless load. Further investigations should enable the comparison with experimental data.

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