Railway multibody dynamics: modeling advances and industrial applications

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EXTENDED ABSTRACT

1 Introduction

This document describes the multibody modeling of railway vehicles and tracks and the industrial applications of the resulting models beyond computer simulation. In the modeling part, the paper focuses on the coordinates and frames selection and a set of simplifications and approximations that can be adopted for gaining computational efficiency while maintaining a reasonable accuracy. In the applications part, the computational models are used to develop on-board observation systems for vehicle and track intelligent maintenance.

2 Multibody modeling of railway vehicles/tracks

The application of multibody dynamics to the railway topic has some features that require the development of specific modeling and computational tools. These features are:

1. The vehicle-track relative motion has more interest that the vehicle absolute motion.
2. Very long-distance simulations are of interest.
3. Complex geometry is involved in the definition of the track and the wheel-rail contact interaction.
4. Modeling the track flexibility is challenging due to its nearly infinite length.

During the last two decades, the research group of the author has developed modeling and simulation tools that account for these features [1]. In many cases, these tools involve the simplification and linearization of different terms of the vehicle-track equations of motion. The set of computational tools summarized in this work includes:

1. Use of non-inertial track frame for the kinematic description of the vehicle-track system.
2. Modeling of the railway vehicle as a set of open-chain mechanisms.
3. Use of a non-uniform set of arc-length, track-relative and joint coordinates.
4. Simplification of generalized inertia forces.
5. Linearization of generalized suspension forces.
6. Knife-edge equivalent wheel-rail contact geometry (KEC method).
7. Moving modes method (MMM) for modeling track flexibility.

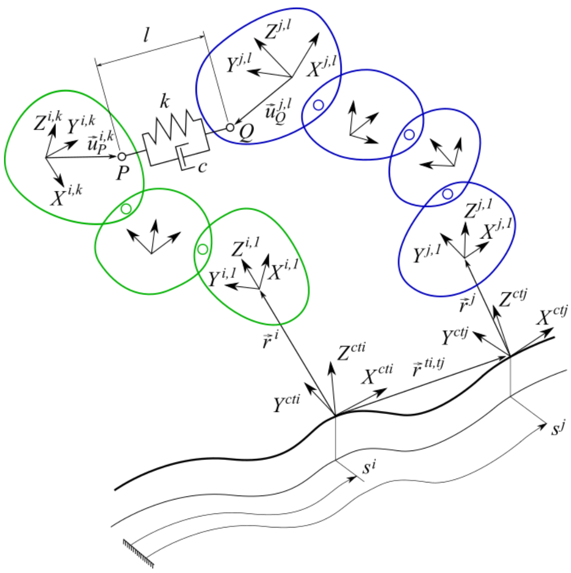

Figure 1: Model of rail vehicle as a set of open-chain mechanisms

The railway multibody models that result with the application of these techniques are well-adapted to long-distance simulations and for the development of new technologies in industrial applications.

3 On-board observation based on multibody models

In multibody dynamics, the most classical application is the computer simulation of mechanical systems. However, other applications of the multibody models that benefit of the use of simple models are emerging for the development of new technologies. In vehicle dynamics, the real-time simulation in on-board computers is a fundamental phase of these emerging technologies:

1. Electronic control units (ECU).
2. Autonomous vehicles.
3. Model-based condition monitoring.
4. Predictive maintenance.

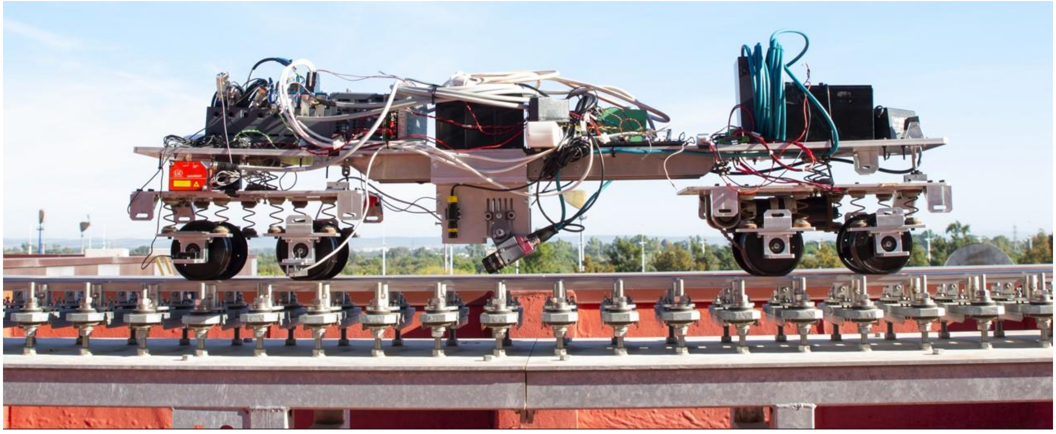

Figure 2: Scale vehicle-track system

During the last decade, the research group of the author works in the development of experimental technologies for the observation of the vehicle dynamics and for the vehicle-track intelligent maintenance [2]. These technologies are first developed in a 90-m scale track installed in the School of Engineering of the University of Seville with a fleet of instrumented vehicles, as can be seen in Fig. 2, and then tested in real vehicle-track systems. The technologies presented in this work are:

1. Track geometry measurement based on inertial sensors and computer vision.
2. Track geometry measurement based on inertial sensors and Kalman filters.
3. Measurement and estimation of wheel-rail contact forces using extensometry and artificial neural networks.
4. Detection of track corrugation using axle-box accelerometers (ABA).

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References

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