A partial numerical linearization of railway multibody equations of motion

Javier F. Aceituno*, José L. Escalona#

*Mechanical and Mining Engineering Department
University of Jaén
Avda. de la Universidad s/n, Dependencia D-044,
23700, Linares, Jaén, Spain
e-mail: jaceitun@ujaen.es

#Mechanical and Manufacturing Engineering
Department. University of Seville
Camino de los Descubrimientos s/n,
41092, Seville, Spain
e-mail: escalona@us.es

ABSTRACT

This work presents a multibody formulation for railway vehicles that applies linearization at vehicle kinematics and equations of motion. The proposed formulation is greatly linearized because it adopts multiple moving reference frames and relative body-track frame coordinates as shown in Fig. 1, against other formulations that employ relative-track frame coordinates [1] or absolute coordinates [2]. This is, each vehicle body has its own track frame that follows the vehicle movement keeping its longitudinal x-axis tangent to the trajectory followed. One of the main advantages of relative body-track frame coordinates is that vehicle-bodies and vehicle to track interactions depend on their relative position with respect to the track, which in most scenarios result in relatively small, generalized coordinates. For this reason, the kinematic and dynamic linearization can be applied with little loss of accuracy and important gained in computational efficiency. However, it has an important drawback that is the need of curvilinear coordinates for the description of the each moving frame.

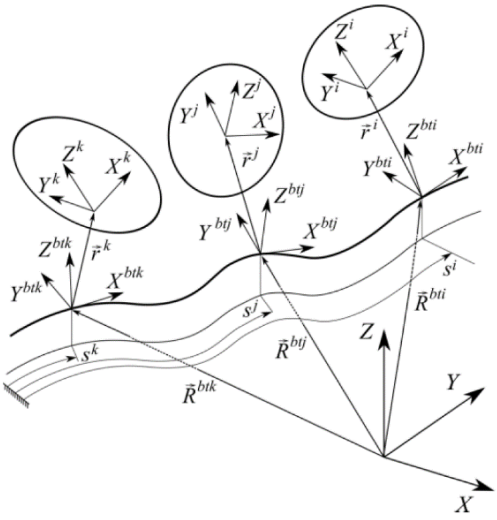

Figure 1: Kinematics of the bodies of a railway vehicle with relative body-track frame coordinates

In this sense, the proposed formulation describes the vehicle as a set of open-chain mechanisms and applies linearization at those rotational matrices when the relative-small angle assumption can be adopted between bodies that comprise the same chain and between different chains. In addition, using symbolic computation to formulate the equations of motion, the velocity transformation matrices used to account for the generalized mass matrices and forces are also linearized taking advantage of the use of relative body-track frame coordinates.

Keywords: moving reference frames, computational efficiency, railway dynamics.

References

[1] Escalona, J. L., & Aceituno, J. F. (2019). Multibody simulation of railway vehicles with contact lookup tables. *International Journal of Mechanical Sciences*, *155*, 571-582.

[2] Shabana, A. A., Zaazaa, K. E., & Sugiyama, H. (2007). Railroad vehicle dynamics: a computational approach. CRC press.