Parameter identification for a scaled railroad vehicle

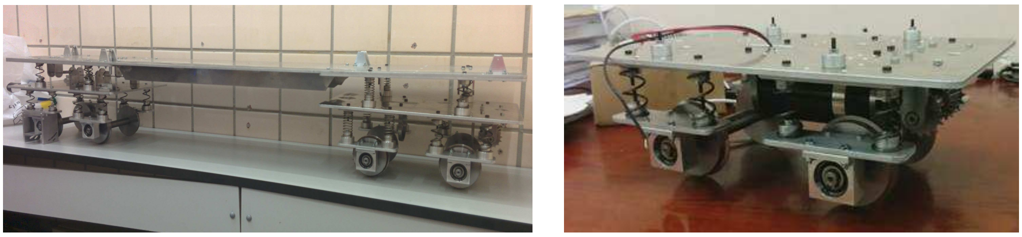
Rosario Chamorro, Sergio Muñoz, José L. Escalona

Higher Technical School of Engineering
University of Seville
C/ Camino de los Descubrimientos s/n 41092, Seville
rchamorro@etsi.us.es, sergiomunoz@us.es, escalona@us.es

Abstract

Parameter identification of a railroad vehicle is very important to have a precise vehicle model. A first step in this parameter identification can be to get information concerning suspension properties. This information can be obtained from the eigenvalue analysis in computer simulations and from modal testing in a real vehicle. Measurement of the model's vibration properties will be useful to compare them with corresponding data produced by the theoretical model. The test will provide accurate estimation of dynamic properties, as natural frequencies, modal damping and description of the mode shapes [1].

The aim of this investigation is to study the effect that the locomotive traction system has on the eigenbehaviour of a railroad vehicle. The eigenbehaviour of the railroad scaled vehicle shown in Figure 1 is analyzed computational and experimentally, and results are compared. In order to get information about the primary suspension the basic modes of the bogie frame studied are the associated to longitudinal oscillation, lateral oscillation, bouncing, rolling, pitching and yawing.



(a) (b)

Figura 1: a)Scaled railroad vehicle; b)Traction motor

The nonlinear equations of motion of the vehicle-track systems, modelled as a multibody system, can take the form of differential-algebraic equations (DAE) if written in terms of the complete set of dependent coordinate. The DAE equations are given by:

$$\begin{aligned}&\mathbf{M}(\mathbf{q})\ddot{\mathbf{q}}+\mathbf{C}_{\mathbf{q}}^{T}(\mathbf{q},t)\boldsymbol{\lambda}=\mathbf{Q}_{v}(\mathbf{q},\dot{\mathbf{q}})+\mathbf{Q}_{app}(\mathbf{q},\dot{\mathbf{q}})\\&\mathbf{C}(\mathbf{q},t)=\mathbf{0}\end{aligned} \tag{1}$$

where $\mathbf{M}$ is the mass matrix, $\mathbf{C}$ is the constraint vector, $\mathbf{C}_{\mathbf{q}}$ is the jacobian matrix of the constraint equations, $\boldsymbol{\lambda}$ is the vector of Lagrange multipliers, $\mathbf{Q}_v$ is the generalized quadratic-velocity inertia forces and $\mathbf{Q}_{app}$ is the vector of applied forces that includes the bodies weight and the tangential wheel-rail contact forces (creep). Vector $\mathbf{Q}_{app}$ contains the normal wheel-rail contact forces if an elastic method is used while these forces are included as reaction forces in the term $\mathbf{C}_{\mathbf{q}}^{T}\boldsymbol{\lambda}$ if the constraint contact method is used [2]. The eigenvalue analysis follows three steps:

1. Calculation of steady motion.

2. Linearization of the equations of motion.

3. Eigenvalue calculation.

The consideration of a motor running in the system changes the mass matrix $\mathbf{M}$ and changes the vector of forces and moments applied $\mathbf{Q}_{app}$. The effects of theses changes in the eigenbehaviour of the system is studied in this work. Results obtained, following the three steps previously mentioned for the eigenanalysis, are validated with the results obtained experimentally from modal testing.

Modal testing is very useful for verifying the theoretical model and for the prediction of the dynamic effect when considering the running motor. Modal testing includes data acquisition and its subsequent analysis. Figure 2 shows the moving hammer that excites the system by impacts and the three accelerometers that measure the response, in X, Y and Z direction. Different experiments, in time and frequency domain, have been done to the following system:

- Vehicle without motor.
- Vehicle with the motor running with 0, 25, 50, 75 and 100 % of the maximum velocity.

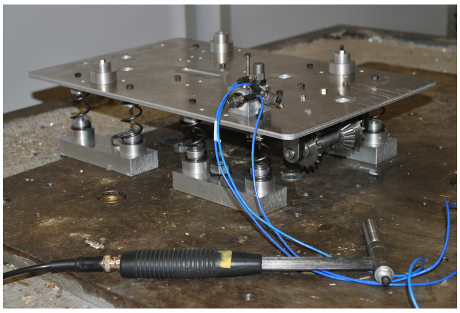


Figura 2: Modal analysis.

The data acquisition in frequency domain of the impulse and the response of the accelerometers gives the FFT and the FRF (see Figure 3). Different methods (SDOF or MDOF) allow the analysis of these data and the calculation of the dynamic properties of the system.

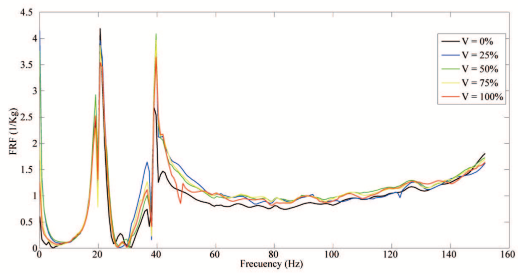


Figura 3: FRF (accelerometer Z and hammer impacting in Z direction)

As mentioned above, in addition to the experiments in frequency domain, tests in time domain have been done. The logarithmic decrement method allows to compared the real part ($\xi\omega_n$) an the imaginary part (ω_d) of the eigenvalues obtained computationally, where ξ is the damping ratio, ω_n is the natural frecuency, and ω_d is the damped natural frecuency.

The calculation of the eigenvalues obtained with the different methods mentioned, computational and experimentally, would allow to validate the model of the railroad vehicle or improve the primary suspension parameters used, in addition to exhibit the influence of the locomotive traction motor in the dynamics of the vehicle.

Referencias

[1] D.J. Ewins. Modal Testing: theory, practice and application. Second Edition. Research Studies Press LTD., 2000.

[2] J. L. Escalona, R. Chamorro, A. M. Recuero. Description of methods for the eigenvalue analysis of railroad vehicles including track flexibility. Journal of Computational and Nonlinear Dynamics, Vol. 7, pp. 041009-1–9, 2012.