ABSTRACT

In this Thesis the dynamic interaction of a railway vehicle with the track is studied through the incorporation in the modelling of the flexibility associated with the elements of the system. The coupled dynamics of the vehicle with the track determines some important railway engineering problems, such as rolling noise and generation of abnormal wear of wheel and rail, which affects the safety, environmental impact and cost of exploitation.

The main contributions of this Thesis are related to the modelling of the wheelset, where in addition to flexibility, inertial effects associated with the rotation are considered. The works carried out range from deepening in the field of Rotors Dynamics in which wheelset models are based, to application to cases of industrial interest where the more advanced assumptions are fulfilled.

A methodology suitable for flexible rotating solids of revolution is proposed to obtain the equation of motion of the wheelset. Taking advantage of the axial symmetry, the model makes use of the vibration mode shapes in a non-rotating frame as basis functions, in order to define the displacements of a particle depending on its spatial position in the undeformed configuration (Eulerian modal approach). Due to the fixed coordinate system, the model is effective in those cases where there is an interaction between the rotating solid and the non-rotating structure, as the case of a wheelset with the track. The considered assumptions allow to consider the dynamics when the solid describes an arbitrary trajectory added to the rotation as well as the effect of internal damping.

Adopting a trajectory-based coordinate system moving along the axis of the track, in combination with the Eulerian modal approach, it is possible to obtain a formulation of the wheelset in curve, whose associated computational cost is very low. This is achieved by combining the equation of motion and the hypothesis of small displacements with respect to the trajectory system. In addition, a wheel-rail flexible contact model is incorporated, which is based on a penalty method that considers the actual profiles of the wheel and rail.

The model of the overall system is performed by adopting a sub-structuring technique, where the different substructures are formulated separately and then are coupled through the forces transmitted between them. Cyclic boundary conditions are taken in the model of the track that reduce the edge effect associated with the finite length of the track. The models are able to consider a straight track as well as a curved track of constant radius.

The works show results associated with a number of practical scenarios that give rise to the high frequency dynamics of the track - unsprung masses system. The effects of irregularities of the wheel surface and the rail head are addressed, such as wheel-flat, the rail corrugation (or harmonic wear) and the presence of random defects of mid and short wavelength (roughness). The simulations presented in this Thesis show the calculation of stresses in the wheelset axle and the wheel-rail contact forces.

Keywords: rotating flexible solid, modal damping, Eulerian coordinates, railway vehicle, vehicle-track interaction, flexible curved track, rail roughness, wheelflat, wheel-rail contact forces, dynamic stresses in the wheelset axle, wheelset axle fatigue.