Abstract

Wheel-rail interaction determines the stability (critical speed and derailment speed), passenger comfort and the wheel life. The rail and wheel wear depends upon the bogie and track design parameters, wheel and rail profiles, type of braking, and operation. In this research, the wheel wear depth or distribution is estimated through a wear prediction tool through co-simulation between a multi-body vehicle dynamics model and a wear evolution model. The outputs of the vehicle dynamics model are the global contact parameters such as the creepage, creep forces, and the locations and dimensions of the contact patches. These global contact parameters are fed into the wear estimation model. The wear estimation involves contact mechanics and wear rate modelling. Kalker's simplified theory of rolling contact, Hertz theory and semi-Hertzian approach have been implemented independently in this research to estimate the local contact parameters from the global contact parameters. The amount of material removed from the wheel surface at different locations (wear distribution) is estimated by using both Archard's wear theory and a wear model developed by the University of Sheffield. In this thesis, the influence of braking (disc and tread braking) along with self-steering and active steering of wheel-set are considered separately. The change in the physical properties such as density, Poisson's ratio and modulus of elasticity of the wheel material due to temperature increase during tread braking is also considered. After estimating the wear distribution, the wheel profiles are updated and several worn wheel profiles are obtained with different levels of wear. The worn wheel profiles are then used in further vehicle dynamics simulation, thus completing the loop in the cosimulation process.

The influences of worn wheel profiles, with different levels of wear, on the dynamic performance, ride comfort and stability (critical and derailment speeds) of the railway vehicle are obtained. The wheel re-profiling schedule is determined by considering both the wear parameters (admissible values) of the wheel profiles and the dynamic performance limits (threshold passenger comfort, critical speed and derailment speed, etc.). Apart from the above mentioned investigations, this research also focuses on the suspension and articulated design of the bogie to study the passenger comfort. An integrated vehicle-biodynamic human model with air spring and nonlinear damper is modelled to determine passenger comfort by using bond graph model and a multi-body dynamics model (developed in ADAMS/VI-Rail). Sinusoidal track excitations due to track flexibilities and/or sleeper spacing are considered. The comfort level of the passenger is determined by the International Organization for Standardization (ISO) 2631 standard for a range of vehicle speeds. Furthermore, a link type active steering mechanism is proposed for a railway vehicle in which the steering control law considers the local track geometry and vehicle speed, and the consequent reduction in the wheel wear rate and the improvement in the dynamic performance is demonstrated. With the implementation of proposed steering mechanism, the wear is reduced by more than 10% as compared to without steering. Also, wear occurs mostly in the tread portion of the wheel and is more evenly distributed which causes increase in wheel life.

Keywords: Wheel wear prediction, passenger comfort, railway vehicle dynamics, disc and tread braking, air spring, active steering