ABSTRACT

The unique profile of rail wheels imparts kinematic constraints on the motion of a wheelset. While such a profile allows a rail vehicle to negotiate a curving track, it also causes sustained vibrations called hunting. It is important to identify the critical hunting speed of a rail vehicle, which requires the integration of wheel-rail contact into the multibody formulation. In railway dynamics, there are two conventional approaches: (a) the elastic approach, in which wheelset has six degrees of freedom with respect to rails, and also wheels are could have penetration with rails. On the other hand, the constrained approach restricts penetration between wheels and rails.

All six degrees of freedom are uncoupled in most formulations that use an elastic approach. However, some motions could be coupled under certain conditions. For example, when wheels have a single-point contact with rails, the wheelset rotates about its roll center. Roll rotation also causes lateral translation. In this thesis, a novel approach is explored to represent the equivalent kinematic constraints of a wheelset. A linkage mechanism that is representative of a wheelset having point contact with rails, moving on a horizontal track is synthesized, by expanding on the concept of instantaneous roll center used in mechanics. Here, the identification of the wheelset's roll center is based on the shape of the wheel and rail profiles. Once the location of the roll center is known, it is shown that the dimensions of virtual links in the mechanism could be derived analytically. In the next step, the kinematic constraints of the linkage mechanism were derived using recursive relations of velocity level constraints using the Decoupled Natural Orthogonal Complement (DeNOC) matrices. In the beginning, multiple assumptions were made to obtain the system's governing equations of motion, notably, the use of knife-edge rails and conical wheels, constant roll center, etc. This led to the links in the mechanism having constant lengths. Moreover, the contact parameters were also kept constant, which allowed us to obtain the governing equations of motion in a basic form that is available in textbooks and literature. The result of these simplifications is then demonstrated by analyzing the critical hunting speed of a suspended wheelset.

In the second portion of the thesis, several simplifications made to the linkage mechanism are removed, to simulate realistic scenarios. It was made possible using the concept of a wheel-rail contact triangle which enabled us to synthesize an instantaneous linkage mechanism for a wheelset. The kinematic parameters such as instantaneous roll center, and varying dimensions of virtual links for a wheelset undergoing hunting motion are illustrated. Ultimately, the dynamics simulation of the linkage mechanism is carried out by taking into account curved wheel and rail profiles. Hunting vibrations are transmitted to the bogies and carbody, causing them to shake excessively. This leads to undesirable ride quality. The latter part of this work involves the development of a serial chain multibody model of a railway carbody. Uneven wear between components could significantly reduce the critical hunting speed of a rail vehicle, and it was found that such variations were not previously taken into account in the hunting analysis. Thus, the multibody model of a railway carbody was subjected to an extensive parametric analysis by varying the properties of the individual components. Through this study, it was possible to systematically comprehend the critical hunting speed of the vehicle concerning the properties of individual components. Accordingly, design proposals are suggested to remedy adverse hunting vibrations.

The dissertation concludes with an investigation of the hunting behavior of a trainset with multiple carbody systems, using an equivalent coupler model that connects adjacent carbodies. By changing the attributes of the cars separately, the critical hunting speeds of two, three, and multi-car trainsets were examined. The hunting behavior of these systems was studied and the conditions under which the number of cars could influence the hunting behavior are listed.

Keywords: Railway dynamics, multibody systems, wheel-rail contact, railway systems,

hunting analysis.