A Study on Biodynamic Models of a Seated Human Body Exposed to Vertical Vibrations and Ride Quality Evaluation

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ABSTRACT

A human body is a very sophisticated dynamic system which is sensitive to whole-body vibrations under low frequency excitation in a sitting posture. As a result, biodynamics of seated human subjects has been a topic of interest over the years, and a number of mathematical models have been established. While much research has been performed on building up specific biodynamic models on the basis of certain experimental data under prescribed testing conditions, a thorough investigation of seated human models has not yet received the same level of attention. In this research, a complete study on lumped-parameter (LP) models for a seated human body exposed to vertical vibrations was implemented. All models were analyzed systematically, and validated by the synthesis of various measured data from published literature. On the basis of analytical study and experimental validation, the four-degree-of-freedom (4-DOF) model developed by Wan and Schimmels was found to be best fitted to test results. In addition, for the cases such as the female pregnant, more mass segments might be needed in the analysis. The 6-DOF model from the modification of nonlinear model established by Muksian and Nash is recommended and integrated with a full-car model to assess the biodynamics of seated normal and pregnant subjects in driving conditions. Furthermore, to obtain the insights of the dynamic responses of a seated body to vertical vibrations, mathematical models of the mechanisms must be at least two-dimensional (2-D) in the sagittal plane. Therefore, the study of multibody (MB) human models with adequate complexity was adopted in this research. Two MB models representative of the automotive postures found in the literature were investigated and validated by various experimental data from the published literature pertaining to the same postural conditions. On the basis of the analytical study and the experimental validation, the 14-DOF model proposed in this study was found to be best fitted to the test results; therefore, this model is recommended for studying the biodynamic responses of a seated human body exposed to vertical vibrations in various automotive postures. Finally, a process to construct quarter-car (QC) models of double-wishbone suspension systems specifically in off-road applications is established. This process first utilized the MB dynamics tool called ADAMS to build one model, and subsequently help determine the equivalent wheel and damping rates of another, called an LP model. Both models have been validated to show very good agreement with measured data form a testing bench. Finally, a construction algorithm for a vehicle ride model is formulated on the basis of both LP and ADAMS modeling and experimentation on the target suspension system. Through this research project, the following contributions can be stated: 1. A systematic and complete study of the LP models of a seated body has been implemented, and two models have been recommended to assess the biodynamics of seated normal and pregnant subjects exposed to vertical vibrations. 2. A procedure for the construction of seated pregnant model and human-vehicle system has been established. A simulation algorithm for the biodynamics of the system exposed to random road excitations has been proposed. 3. A 2-D MB model for a seated body exposed to vertical vibrations in various automotive postures, and the modeling procedure have been proposed. 4. A cost-effective approach for the construction of a QC model of a suspension system and vehicle ride model has been proposed to evaluate the suspension performance and vehicle ride comfort. It is believed that the study presented here provides a clear understanding of the dynamics of a suspension system as well as the biodynamics of a seated human body exposed to vertical vibrations, and that it may offer vehicle engineers a good reference in the design of vehicle suspension systems.

Keywords : whole-body vibrations ; lumped-parameter model ; multibody model ; quarter-car model ; half-car model ; full-car model

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