Biodynamic Model of the Seated Human Body under the Vertical Whole Body Vibration Exposure

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(Received 13 January 2017; accepted 15 February 2019)

The seat-to-head transmissibility and apparent mass characteristics are measured for the seated human subjects exposed to vertical whole-body vibration in the 0.5–20 Hz frequency range at a vibration magnitude of 1.0 m/s² rms. The experiments are conducted on test subjects seated in an upright posture. A biodynamic model has been developed for bio-mechanical parameters that are estimated on the basis of identified biodynamic responses. The parameters identification technique employs a genetic algorithm for the solution of the function comprising sum of squared magnitude and phase errors related with target values of seat-to-head transmissibility and apparent mass. The developed model presents the target values of magnitude associated with apparent mass and seat-to-head transmissibility. The natural frequencies of the model have been found at up to 5.0896 Hz. The model also presents the resonant frequencies calculated on the basis of both biodynamic response functions very close to that found for seated human body experimentally.

1. INTRODUCTION

The moving vehicle parts, suspension system and vehicle-terrain interactions cause vibrations in the vehicle compartment. During the journey, drivers and passengers are exposed to low frequency vibrations i.e. frequencies up to 20 Hz. The vibrations are transmitted to the human body from the various interfaces of human body and vehicle parts such as floor, seat and backrest etc. Researchers noted that these vibrations have ill-effects on the driver as well as on the passengers such as discomfort, impaired performance and health effects.1–3 The effects of whole body vibration (WBV) vary with amplitude, frequency, type of vibration, subject’s mass, height, sex etc. A large number of variables play their role in the human body dynamics under the exposure of whole body vibration. Various past studies have attempted to quantify the effects of whole body vibration by considering above stated variables, with the help of frequency response functions such as seat-to-head transmissibility (STHT), driving-point mechanical impedance (DPMI) and Apparent mass (APMS).3,5

The human body is very complex in nature and considerable variations in dynamic response have been observed above the 2 Hz frequency of whole body vibration.6 During the development of a vehicle seat system, computer simulations of the human body and seat systems are essential for predicting the dynamic responses. In order to perform computer simulations, a dynamic model of the human body, along with the seat, is required. Various models of the human body under WBV exposure have been proposed in the literature.7,8 Many models are based upon the frequency response functions. The restoring and damping parameters of the human body model are calculated by matching the model dynamic response with one or two of the frequency responses: STHT, DPMI and APMS. These reported human body models vary from single degree-of-freedom (DOF) to linear & non-linear multi-DOF models.

A two-DOF mechanical simulator has been proposed to account human body dynamics for testing seat dynamics under the exposure of vibration.9 Seat performance of the vehicle not only depends upon the design of seat suspension system but also on the dynamics of seated human body.2,3

A Six-DOF non-linear lumped parameter model was proposed by Mukhsan and Nash.10 The lumped masses were connected by restoring and damping elements, representing the elastic and damping properties of the connective tissue between the body segments. Mukhsan and Nash recognized the possibility of a frequency dependent damping coefficient in accord to frequency dependent muscle forces.11 The model proposed by Mukhsan and Nash was lumped together with the tractor’s seat,10 chassis and tires by Patil and Palanichamy.12 Qassem et al. proposed an eleven-DOF linear model for the seated human body under the exposure of vibration.13 Moreover, the spinal column was segmented into cervical, thoracic and lumbar spines with the same spring constant and damping coefficient. The basis for selecting the masses of these spinal segments was not reported in the study. Another eleven-DOF linear model for pregnant woman was proposed by Qassem and Othman.14 The responses of models13,14 did not match the experimentally identified ranges for the biodynamic responses.7

A four-DOF model was reported for essential dynamics of seated human body under the exposure of vibration.15 Another four-DOF linear model for a seated human body was proposed based upon STHT and DPMI data collected by experimentation with human subjects.5 All factors such as damping and elastic coefficients were obtained through an optimization procedure with human body anthropometric and biodynamic data...