A Biomechanical Seven DOF Model as a Seated Human Exposed to Vertical Vibration Using Genetic Algorithm

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Abstract – In this paper, a lumped-parameter biomechanical model with seven degrees of freedom as a seated human without backrest support exposed to vertical vibration is presented. This model incorporates seven concentrated masses connected in the vertical direction by means of springs and dampers representing dynamic of the body parts. Experimental data is used to find the stiffness and damping parameters of the model. The data includes values of seat to head (STH) transmissibility, driving point mechanical (DPM) impedance, and apparent (AP) mass when the frequency is varied in the range between 0.5 to 20 Hz. The solution of differential equations of the system is transformed into the frequency domain. The multi-objective function is used to obtain theoretical results similar to three different experimental data. The unknown coefficients are calculated by a genetic algorithm within MATLAB. Improved results, in comparison with previous models, are achieved from the presented model. Finally, modal analysis of the model is performed within ADAMS and the resonance frequencies of the human body are calculated. The results may be used to design the seat and suspension parameters so that the transmitted vibrations are reduced and ride comfort is enhanced.

Keywords: Human model, Vertical vibration, Genetic algorithm, Multi-objective optimization

I. Introduction

Several biomechanical models of human body exposed to vibrations have been developed in recent years. Among all finite element, lumped parameter and multi-body models, lumped parameter models were shown to be the most appropriate. In these models, human body is assumed to be composed of several concentrated masses linked together by some springs and dampers. These models are readily analyzed and can predict the experimental results rather accurately. In what follows, some important works in this field are reviewed.

Wei and Griffin [1] in 1998 developed one- and two-dof models based on an experimental work by Fairley and Griffin [2]. They used the absolute value and phase angle of the apparent mass to verify their results. The same authors applied the one- and two-dof models to the seat to head transmissibility [3]. Stein [4] developed a 3-dof model based on the apparent mass of 13 seated individuals. His model incorporated displacement only in the fore-aft or x-direction. The backrest angle was considered to be less than 10°; the results were studied for several conditions of contact with the backrest.

Nawayseh and Griffin [5] in 2009 proposed a 3-dof biomechanical model which took account of displacements in vertical and horizontal directions, as well as rotation. This model was based on experimental data of apparent masses of 12 people in the frequency range between 2 Hz and 10 Hz along the vertical and horizontal axes. Wan and Schimmels [6] suggested a 4-dof model for the seated position. This model incorporated four concentrated masses linked together by five pairs of springs and dampers. Later, this model was included in a complete car model by Wanger and Liu [7] to study the results of car-human system and ride comfort.

Boileau and Rakheja [8, 9] performed extensive experiments in 1998 and developed a linear 4-dof model. They used an optimization method to verify their model. Matsumoto and Griffin [10] proposed 4- and 5-dof models with extensional and torsional springs and dampers; however, these models could not be accurately fit to experimental data. A 6-dof model was proposed by Mukshian and Nash [11] with the interactive forces considered as nonlinear. This model was later modified by Patil [12] by adding a spring and damper under the hip and neglecting the internal forces. Next, this model was included in a tractor-driver system [13, 14] to study its vibration behavior.