BIOMECHANICAL MODEL OF THE HAND-ARM SYSTEM TO SIMULATE DISTRIBUTED BIODYNAMIC RESPONSES

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Introduction

A number of mechanical-equivalent biodynamic models of the human hand-arm have been developed for potential applications in design of tools and vibration control mechanisms. The vast majority of the reported models have been derived using measured driving-point impedance (DPMI) and do not relate to anatomical structure of the hand-arm system.[1] The models assume hand-arm structure with a fixed support suggesting negligible transmission of vibration beyond the shoulder, although a few studies have reported considerable vibration at the shoulder[2] and the head[3] under exposure to hand-transmitted vibration (HTV). Moreover, the validity of the models in predicting vibration transmission properties of the human hand-arm has not been established, which raises concerns related to their applicability for characterizing vibration-induced loadings and responses of the different hand-arm substructures. This study presents a hand-arm model with a representative biomechanical structure derived on the basis of simultaneously measured DPMI and localized vibration transmissibility responses.

Methods

Fig. 1 shows the hand-arm model structure in the bent-arm posture, where m_i are segment masses, and (c_i,k_i) and (C_i,K_i) represent the linear and rotational visco-elastic parameters, respectively. The shoulder constraint, employed in all of the reported models, is relaxed by considering a lumped mass due to the trunk to account for the reported considerable vibration of the head.[3]

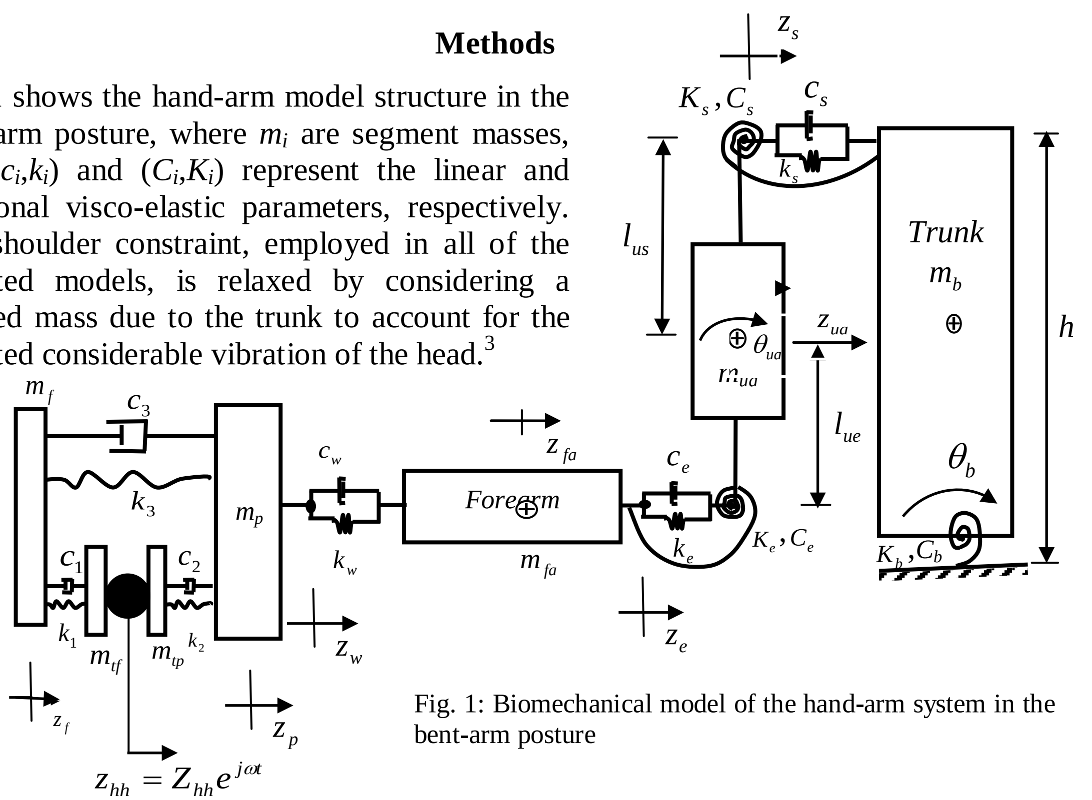

Fig. 1: Biomechanical model of the hand-arm system in the bent-arm posture

Three different target functions were considered for model parameters identification based on: (i) DPMI data alone; (ii) segment vibration; and (iii) combined DPMI and segment vibration data, while hand-arm anthropometry was used to define the inertial and geometry data. Experiments were performed to simultaneously measure DPMI and segment (wrist, elbow and shoulder) vibration responses of six subjects grasping a 40 mm diameter handle subject to z_h-axis broadband random excitation (a_{hw}= 5.25 m/s^2). The subjects applied different levels of controlled grip and push forces during experiments.

Results and discussions

Fig. 2 illustrates comparisons of the measured data with responses of the model derived from the different target biodynamic responses. The model derived on the basis of DPMI alone resulted in very good agreement between the model response and measured data in DPMI alone, with considerable errors in vibration transmissibility responses. The model based on the vibration transmissibility target functions alone resulted in reasonably good agreements between the mean measured and the model transmissibility responses, with poor agreement between the measured and model DPMI responses. The minimization of error in DPMI alone, which has been invariably applied for deriving hand-arm vibration models, provided the most rapid convergence of the solutions, while the resulting model could not be applied for predicting segment vibration responses, and the relative motions across the hand-arm segments for estimating distributed absorbed power. Consideration of both the segment vibration and DPMI as target functions resulted in an acceptable agreements in both the biodynamic responses, which would be better suited for study of distributed responses. The model parameters and responses further suggested strong coupling between the HTV and the trunk vibration.

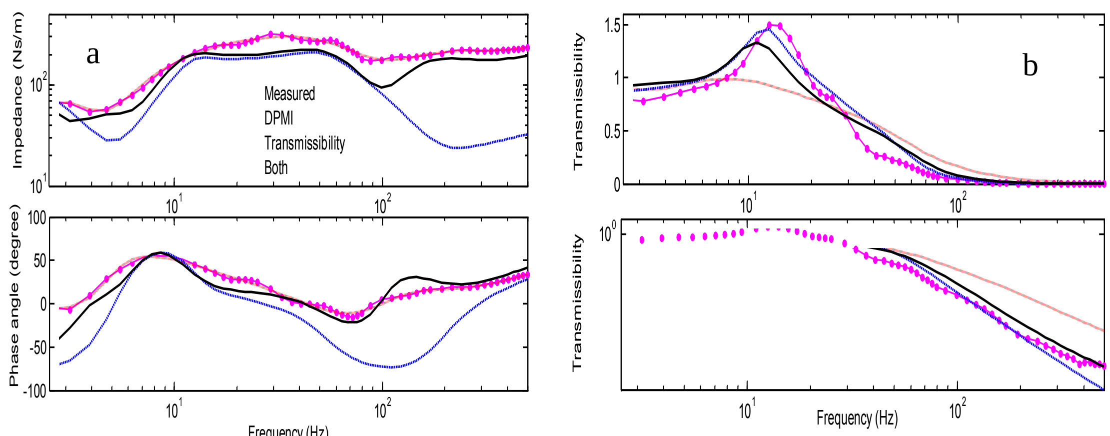

Fig. 2: Comparisons of measured DPMI and z_h-axis elbow vibration data with responses of the model derived using three different target functions.

References

1. Rakheja S, Wu JZ, Dong RG and Schopper AW (2002). A comparison of biodynamic models of the human hand-arm for applications to hand-held power tools, J Sound & Vib, 249 (1), 55-82.

2. Reynolds DD and Angevine EN (1977). Hand-arm vibration. Part II: vibration transmission characteristics of the hand and arm, J Sound & Vib, 51, 255-265.

3. Sakakibara H, Kondo T, Miyao M, Yamada S, Nakagawa T, Kobayashi F and Ono Y (1986). Transmission of hand-arm vibration to the head, Scan J of Work Environ Health, 12**,** 359-361.