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MECHANICAL IMPEDANCES DISTRIBUTED AT THE FINGERS AND PALM OF THE HUMAN HAND SUBJECTED TO 3-D VIBRATIONS

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INTRODUCTION

Vibration biodynamic response of the hand-arm system is useful for designing tools and anti-vibration devices, for understanding the vibration-induced disorders, and for helping to develop the location-specific frequency weightings for assessing the risk of the hand-transmitted vibration exposure. One of the practical approaches to study the response is to measure the mechanical impedance of the system at the driving-point. Although a considerable number of studies on the impedance along the forearm direction (z_h-axis) have been reported, the studies of the impedances in x_h- and y_h-axes have been very limited, partially because it is difficult to apply a push force orthogonal to the vibration direction on a single axis vibration testing system. Although the recent developments in 3-D vibration test systems have made it possible to measure impedance responses to multi-axis vibration under controlled grip and push actions[1,2], a single study has reported the 3-D impedance only in the preliminary stage[3]. Furthermore, no study has investigated the impedances distributed at the fingers and the palm of the hand in the x_h-axis and y_h-axis, which are required for further modeling studies. Therefore, the objectives of this study are to measure the 3-D impedances distributed at the fingers and the palm of the hand and to examine their basic characteristics.

METHOD

Six male and six female subjects participated in the impedance measurement. As shown in Fig. 1, the hand and arm postures used in the measurement were within the ranges specified in ISO 10068 (1998)[4]. Also consistent with this standard, each subject applied 30 N grip and 50 N push on a 3-D instrumented handle equipped with two tri-axial forces sensors (Kistler 9017B/9018B) and a tri-axial accelerometer (Endevco 65-100), which was used to

Fig. 1 Test setup and subject posture

monitor the grip force and to measure the impedances distributed at the fingers and the palm of the hand in the three orthogonal directions. The push force was measured using a force plate (Kistler 9286AA) on which the subject was standing on during the measurements. In each axis, an identical broad band random vibration spectrum in the 16 to 500 Hz range was applied as the excitation. To examine the impedance differences between the single and the three-axis excitations, the 1-D impedance for each axis was also measured in a separate test. Three trials were performed for each test treatment, each lasting 30 seconds.

RESULTS AND DISCUSSION

Fig. 2 shows the impedances distributed at the fingers and the palm the hand, together with their sum that represents the total impedance of the entire hand-arm system[5]. In all three directions, the impedance distributed at the fingers is much less than that at the palm at frequencies below 100 Hz, which suggests that the effective mass of the fingers at such frequencies is much less than that of the palm. Whereas the magnitudes of the impedance at the fingers in the three directions are fairly comparable, the peak impedance at the palm along the forearm direction is obviously greater than those in the other two directions. The fundamental resonant frequency of the impedance at the palm is lower than that observed from the fingers' responses. The resonant frequency also generally varies with the direction of the vibration exposure but those at the palm are fairly consistent in all three directions (about 40 Hz).

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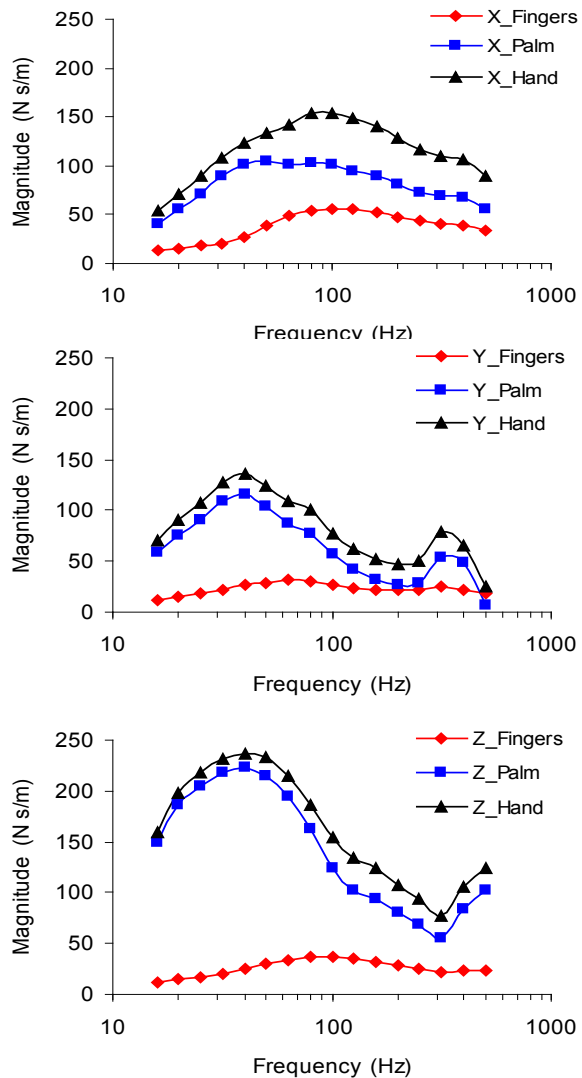
Fig. 2: Impedances in three orthogonal directions