Bad Vibrations

An Investigation of the 3-D Vibration Transmissibility on the Human Hand-Arm System Using a 3-D Scanning Laser Vibrometer

Introduction

Vibration transmissibility on the hand-arm system is very important in order to understand and simulate the biodynamic response of the system. Such knowledge can be further used to help understand vibration-induced discomforts, injuries, and disorders. Both conventional accelerometers (which, however, affect the results due to their mass) and single-axis laser vibrometers [1, 2, 3] have been used to measure the transmitted vibration. Further simulations of the system require multi-axis transfer functions. Therefore, the objective of this study is to investigate the vibration transmissibility on the human hand-arm system subjected to vibrations in three orthogonal directions (x_h, y_h, and z_h).

Method

Seven healthy male subjects participated in the study. As shown in fig. 1, the experiment was carried out on a novel 3-D vibration test system (MB Dynamics, 3-D Hand-Arm Test System). The z_h direction is along the forearm, y_h direction is along the centerline of the instrumented handle in the vertical direction and x_h direction is in the horizontal plane normal to y_h-z_h plane. Each subject was instructed to maintain grip and push forces at 30±5 N and 50±8 N, respectively, with his dominant right hand with elbow angle between 90° and 120°, and shoulder abduction between 0° and 30°.

The vibration controller was programmed to generate broadband random vibration in the frequency range of 16 – 500 Hz along each direction. The overall rms acceleration in each direction was 19.6 m/s². The coherence of the three axial spectra was taken as 0.9. The three-axis accelera-

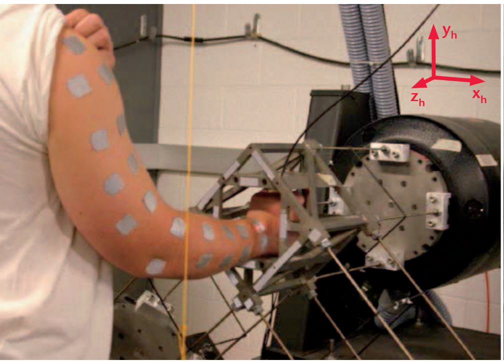

Fig. 1: 3-D hand-arm test system, together with the posture of a test subject.

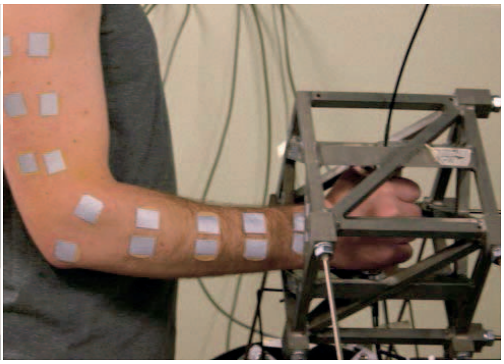

Fig. 2: Attachment of retro-reflective tape.

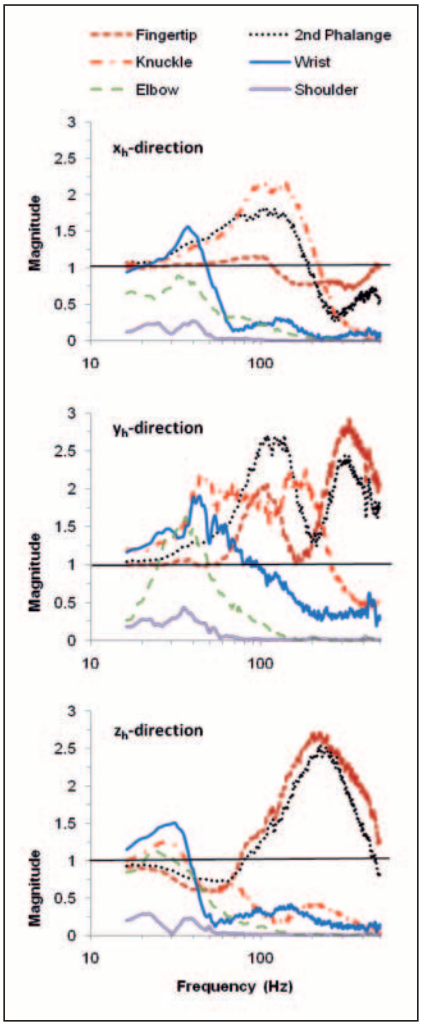

Fig. 3: Magnitudes of the tri-axial vibration transmissibility at the different locations.

tions on the handle were measured using a tri-axis accelerometer installed inside the handle, which provided the reference signals for deriving the vibration transfer functions in the three directions.

The vibration transmitted to the top surfaces of the major substructures of the system (fingers, back of the hand, wrist, forearm, upper arm, and shoulder) was measured using a Polytec PSV-400-3D Scanning Vibrometer. To avoid the effect of hairs and to obtain a good reflection, a piece of retro-reflective tape was attached to a piece of first-aid tape that was firmly attached to the skin of the hand-arm system at the desired measuring locations, as shown in fig. 2. Each transfer function was expressed in the frequency domain from 16 to 500 Hz, with an equal frequency interval of 0.5 Hz.

Preliminary Results and Discussions

The measured transmissibility functions varied greatly among the subjects but their basic distributions are similar and are demonstrated here using the data measured with one of the subjects. Fig. 3 shows the magnitudes of the tri-axial transmissibility, which is generally a function of frequency, measured at six important locations. The function varied greatly with the measurement location and vibration direction. There is at least one dominant peak or resonance in each transmissibility function. The dominant resonances at the wrist, elbow, and shoulder in the x_h- and y_h-directions were in a similar frequency range (30 to 50 Hz). In the z_h-direction, they were at marginally lower frequencies (20 to 40 Hz). The resonances on the fingers were at higher frequencies and they varied in a wide frequency range (80 to 400 Hz).

The resonances observed at the wrist, elbow, and shoulder were fairly consistent with the first resonance observed in the driving-point biodynamic response [4]. This suggests that the entire hand-arm system vibrates more or less in phase in this resonance frequency range and that this resonance primarily depends on the biodynamic properties of the palm-wrist-arm substructures. The major finger resonance was also well correlated to that observed in the corresponding driving-point response, suggesting that it primarily depends on the biodynamic properties of the fingers.

A reported study [5] found that the frequency dependence of the vibration power absorption density (VPAD) of a finger is similar to that of the vibration transmissibility at frequencies higher than the first resonance of the hand-arm system. While the finger VPAD may be a good measure of the finger vibration exposure, the finger resonances observed in this study suggest that the frequency weighting defined in the current standard (ISO 5349-1, 2001 [6]) is unlikely to be suitable for assessing the risk of the finger vibration injuries and disorders.

References

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Authors · Contact
Daniel E. Welcome, **zzw8@cdc.gov**;
Ren G. Dong, Xueyan S. Xu, Christopher Warren, Thomas W. McDowell and John Z. Wu

Engineering & Control Technology Branch, Health Effects Laboratory Division, National Institute for Occupational Safety and Health (NIOSH), Morgantown, West Virginia, USA

