Biodynamic responses at the fingers and the palm of the human hand-arm system under different vibration sources

Massimo Cavacece [a] Graziella Aghilone [b]

[a] *Department of Civil and Mechanical Engineering*
University of Cassino and Southern Lazio, Via G. Di Biasio n.43 , 03043 Cassino (FR) Italy,
e-mail: cavacece@unicas.it

[b] *Pharmacy and Medicine Faculty, University La Sapienza of Rome,*
Via Regina Margherita n.273, 00198 Rome (RM) Italy,
e–mail: graziella.aghilone@uniroma1.it

Abstract

This study proposes a statistical analysis of a lumped mechanical model of the hand and upper arm gripping an object. The lumped mechanical model is represented by five degree-of-freedom. It simulates model the distributed biodynamic responses of the hand-arm system exposed to vibration. They can be used to further study the biodynamic responses and their applications.

Keywords:
Hand; Finger; Hand-arm vibration; Hand-transmitted vibration; Biodynamic response

Introduction

The objective of this study is to develop analytical models for simulating driving-point biodynamic responses distributed at the fingers and palm of the hand under different vibration sources [1]. It is evaluated the real part of the mechanical impedance in the frequency domain [2]. The responses of the proposed lumped mechanical model are analyzed under different hand actions. The evaluation is developed by statistical analysis, numerical approaches and experimental investigations. The results show that the responses predicted from the lumped mechanical model agree reasonably well with the measured data. The variations in the responses under different hand actions are discussed in view of the biological system behavior of human hand-arm system. The proposed models are considered to serve as useful tools for design of vibration isolation methods, and for developing a hand-arm mathematical model for vibration analysis of power tools [3].

Methods

The lumped mechanical model of the hand and upper arm gripping an object is represented in Fig. 1.
Kernel density estimation (KDE) is a non-parametric method to estimate the probability density function of a random variable. The characteristic frequencies of hand-arm system can be identified by KDE to develop the comparison between human hand-arm system and the 5-DOF model structure.
The analysis of variance has been developed by the Kruskal – Wallis Test, a non-parametric method.
The ratio between two successive characteristic frequencies can be described by the Markov Chains.

Results

In order to verify the differences obtained in the case of different persons, results are obtained with the following cases: combined position of wrist, elbow and shoulder (Wrist Extension, Wrist Flexion, Wrist Neutral 90° Bended Arm, Wrist Neutral Extended Arm); excitation along Xh- Yh- Zh-axis; different combinations of push force and grip force (Grip Force 20 N – Push Force 0 N, Grip

Force 80 N – Push Force 0 N, Grip Force 80 N – Push Force 60 N and Grip Force 110 N - Push Force 0 N); vibration amplitude of a_w=15 m/s^2 and a_w=30 m/s^2 [4].

Discussion

The antagonistic action between grip force and push force influences muscle tension of human hand-arm system. The vibration amplitude influences also the stiffness coefficient of substructures represented by finger skin tightly in contact with the handle. Analyzing measured data along Xh- Yh- Zh-axis, it can be affirmed that the human hand-arm system is very sensitive to vibration direction in a wide frequency range. The process with combined position of wrist, elbow and shoulder shows the stabilizing effect of the wrist and the synergistic action between wrist and fingers. There is strong interaction among elbow posture, wrist posture, and finger posture.
Distributions of measured data have long tails (outliers). The apparent mass due to the human hand-arm system approaches a very low value at high frequencies. The mass cancellation of the measured impedance data at high frequencies could also provoke errors in measured data.

Conclusion

The measured responses distributed at the fingers and palm have been reported in this study, conducted with four subjects and four different hand actions. The methodology proposed in this study provides a better evaluation of health risks associated with exposure to hand-transmitted vibration from power tools. The results obtained can also be used in handle design for new tools in order to minimize potential harm to operator's health.

References

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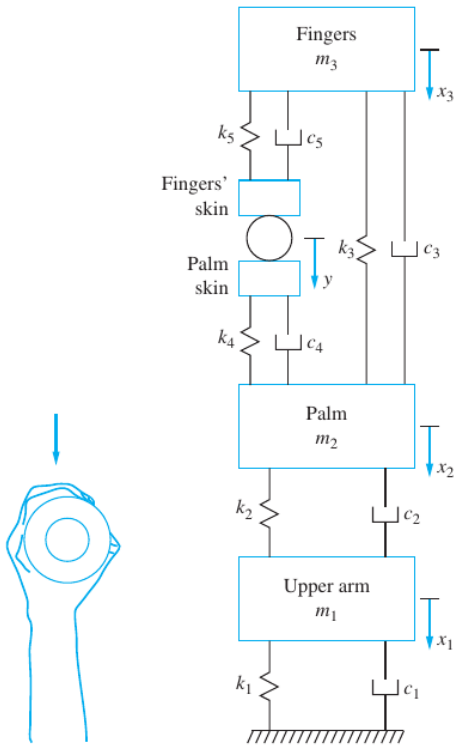

Figure 1: Lumped Mechanical System

Corresponding address

Massimo Cavacece
Address of author named first