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A COMPARISON OF REPORTED MECHANICAL IMPEDANCE DATA OF THE HUMAN HAND-ARM SYSTEM

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Introduction

Many experimental studies of the mechanical impedance of the human hand-arm system have been reported in the literature. This study compares and evaluates the data that were measured in the Z_h-direction (along the forearm). The objective was to examine the validity of these data, especially those used for the synthesis of the impedance values recommended in the current ISO-10068 (1998).

Method

While one set of test data used in this study was obtained directly from the current researchers, the others were digitized from the published curves. The response in the Z_h-direction at frequencies lower than 100 Hz depends mainly on the mechanical properties of the palm-hand-arm system (Dong et al., 2003). As a rough approximation, it is reasonable to model the palm soft tissue as a spring-damper component and the rest of the hand-arm components as a lumped mass on the spring-damper for the simulation of the dynamic behaviors in the frequency range. This simple computer model was used to evaluate the reported data. Data measured with carefully calibrated instrumentation (Dong et al., 2003) were also used as a basis for the evaluation.

Results

Several typical examples of data reported in the literature are presented in Figure 1. Obviously, considerable differences exist among these data. In the 20-63 Hz frequency band, a resonant magnitude exists in the data from the majority of the studies, which is further confirmed from the near zero phase angle. However, data from one of the studies show a fairly flat response in this frequency range. While the phase angles are generally between 0^0 and 60^0 at frequencies greater than 500 Hz, it is near 90^0 from one of the studies, and is negative from another study.

Figure 2 shows the comparison of the results from the modeling and an experiment (Dong et al., 2003), together with the ISO-recommended mean values (ISO 10068, 1998). While the experimental data show a fairly good agreement with the theoretical predictions in the resonant frequency range, the ISO-recommended values do not reasonably fit this model.

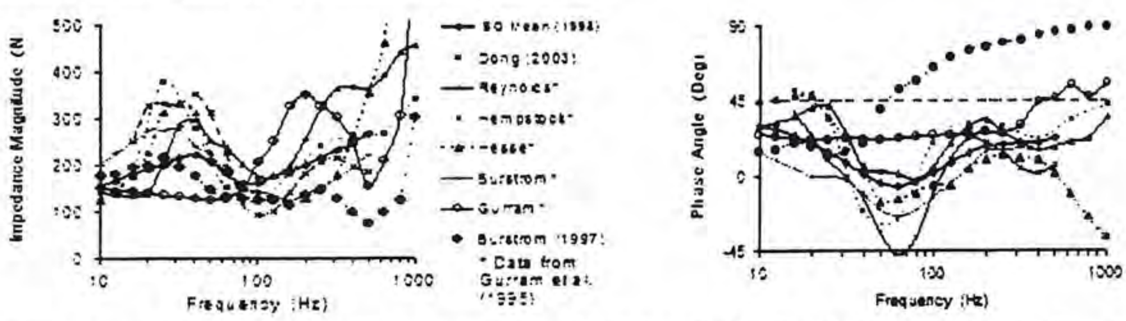

Figure 1 A comparison of several typical sets of MI data (in Z_h-direction) reported in the literature.

Discussion and Conclusion

Many factors and sources could result in the large variations in the MI data, which may be broadly classified into (1) natural factors and (2) instrumentation problems. The natural factors include individual differences, coupling force, hand-arm posture etc. Therefore, the specific working postures, coupling conditions, and worker population should be taken into account when a set of the MI data is selected for a specific tool design and/or a vibration transmission analysis.

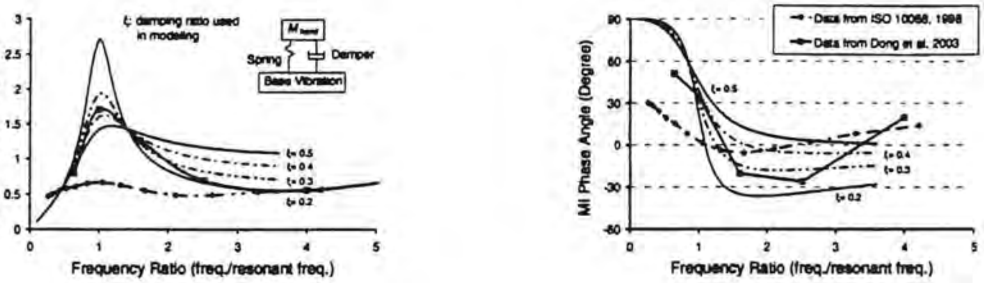

Figure 2 A comparison of the normalized impedance data from the computer modeling, ISO-10068 (1998), and a previous study (Dong et al. 2003). The normalized magnitude = IM "(M_e×ù $_n$), where IM is the impedance, M_e is the hand-arm effective mass (1.4 kg), and ù $_n$ is the resonant frequency

The possible instrumentation problems include sensor errors, poor performance of the instrumented handle, inappropriate handle mass cancellation, and errors in the program used for the impedance calculation. Practically, there are always some instrument errors because no instrumentation is perfect. The resulted errors may not be critical if they are in a certain range. However, a large instrumentation error could lead to erroneous conclusions. For example, the near 90^0 phase angle at frequencies >500 Hz shown in Fig. 1 suggests that the human hand would behave like a solid rock with little elasticity and damping at these frequencies, which is unrealistic. As the modeling results and many experimental data indicated, there should be a resonance in the 20-63 Hz frequency band. However, some data show a fairly flat response in this frequency range (see an example in Fig.1). Unfortunately, some of the questionable data were used for the synthesis of the ISO-recommended values (Gurram et al., 1995). This explains why the ISO mean values have a large deviation from the theoretical prediction. If the data measured in the Z_h-direction is invalid, the data measured in the other directions using the same instrumentation may also be doubtful. These observations cast doubt on the validity of the current ISO-recommended impedance data. Consequently, the computer models established based on these data may not be valid either, which at least partially explains why the models recommended in the same ISO standard have problems for practical applications (Rakheja et al., 2002). The invalidation of the models may further jeopardize another ISO standard (ISO 13753, 1999) for glove material evaluation. Based on these observations, this study concluded that some of the reported MI data are not reliable and the current ISO-10068 needs a major revision.

References

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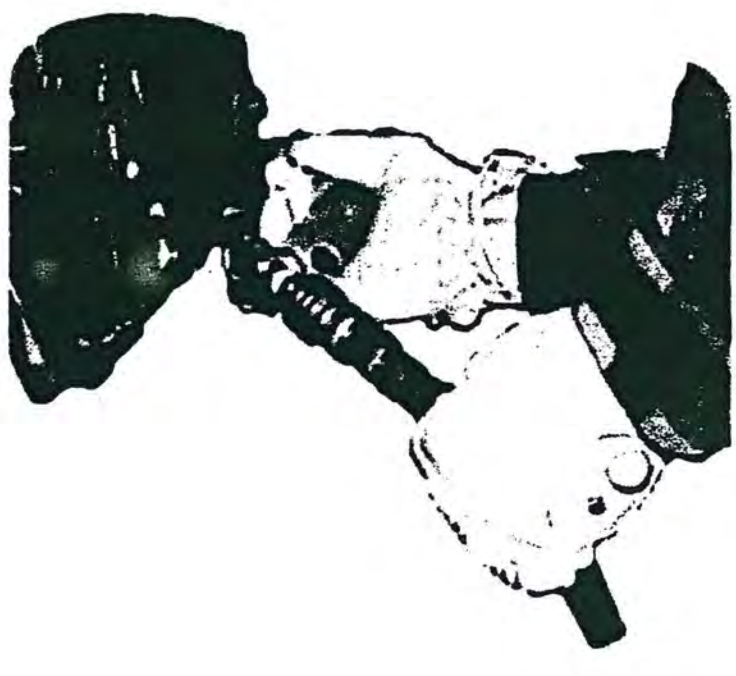

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