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PREDICTION OF TOOL-SPECIFIC GLOVE ATTENUATION PERFORMANCE IN REAL WORKPLACE

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The use of vibration-reducing (VR) gloves has been recommended to reduce vibration transmitted through hand-held power tools to the hand. Although the test protocol of vibration attenuation performance of VR gloves has been specified in ISO 10819, vibration-isolating performance of VR gloves for real tool vibration is not clear for power tool operators in real workplaces. The author previously reported the measurement method of the transfer function of the glove-hand system using an interpolated ISO-signal. In this study vibration-isolating performance of vibration-reducing gloves for real tool vibration signals was predicted by using the transfer function method. The overall weighted acceleration values of the gloved hand could be estimated for too-specific vibrations within a tolerable error.

Keywords: hand-arm vibration, gloves, tool vibration

1. Introduction

Vibration-reducing (VR) gloves are recommended to be used to reduce the vibration which is transmitted to the hand during hand-held tool operation. However the use of VR gloves in real workplaces has been limited. Although the measurement and evaluation method of vibration attenuation performance of gloves has been defined in the International Standard ISO 10819 (2013) [1], the frequency range (25-1,600 Hz) of the test vibration signal specified in the standard is not consistent with the frequency range (6.3-1,250 Hz) required to evaluate exposure to hand-arm vibration (HAV) on the basis of ISO 5349-1 (2001) [2]. The inconsistence of these frequency ranges makes it difficult to evaluate the effect of the use of VR gloves on reduction of exposure to HAV in practical workplaces.

The author previously reported the measurement of the transfer function of the glove-hand system using an interpolated ISO-signal [3]. Because of nonlinear responses of the glove–hand system to vibration, the vibration transmissibility of the glove–hand system is affected by several factors: grip and push forces at the handle, arm posture, inter-subjective differences, frequency contents in vibration signal and so on [4]. If the influence of these factors is trivial, this method can be effective in estimating the exposure of the gloved hand to tool vibrations in real workplaces.

The aim of this study was to validate the measurement method using the extended test signal of vibration transmissibility of gloves for tool vibrations. The final goal in this study was to establish a framework of association of glove vibration transmissibility with the evaluation of improvement on vibration dose level with a use of VR-gloves in practical workplaces.

2. Subjects and Methods

2.1 Subjects

Four healthy male subjects in twenties participated in the experiments. None of the subjects have been exposed to high levels or long periods of HAV occupationally or in their leisure time activities.

The experiments were approved by the Research Ethics Committee of Japan National Institute of Occupational Safety and Health. All the subjects underwent an explanation of the test procedure and gave their written informed consent to participate in this study.

2.2 Test signal

A test signal was designed by interpolating the low frequency range of 5.0 to 25 Hz at 1/3 octave band centre frequency for the glove test signal specified in ISO 10819 (2013). As shown in Figure 1, a constant velocity of 0.0128 m/s at 25-250 Hz in the ISO test signal spectrum was extended to 5.0-25 Hz (see the red curve shown in Fig. 1). The vibration spectrum of the extended vibration test signal at 315-1,600 Hz was the same as the ramp-down spectrum defined in the current ISO 10819 (2013). The weighted rms acceleration of the extended vibration signal thus increased to 5.47 m/s^2 compared to that of the conventional ISO test signal (4.95 m/s^2).

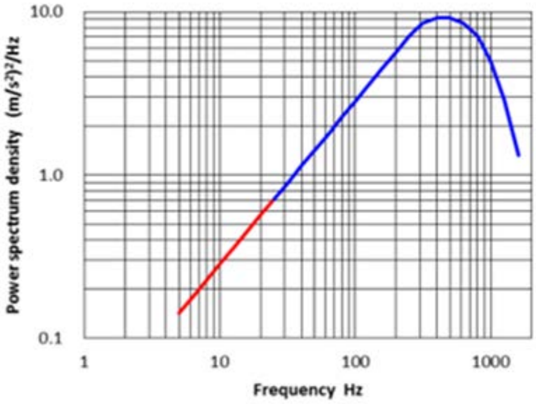


Figure 1 The vibration test signal proposed in this study.

Also vibration spectra of three different power tools obtained from a previous field study were prepared in this study. The power tools selected in this study were a random sander, a hammer drill, and an impact wrench. These tool vibration spectra were resampled at 1.25 kHz to obtain tool vibration test spectra. The tool vibration spectra, the duration of which was arranged to 60 seconds, were reproduced in a uniaxial hand-arm vibration system that satisfies the ISO 10819 requirements. The vibration spectra of the tools used in this study are shown in Figure 2.

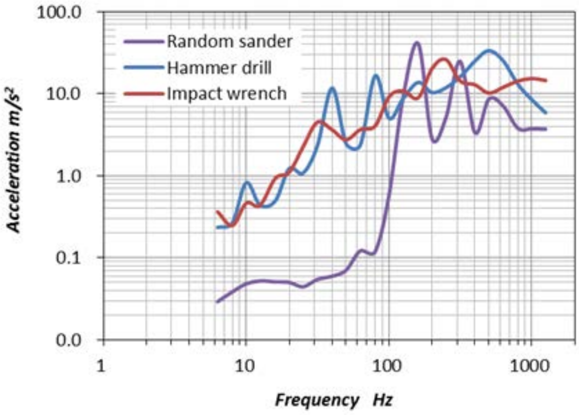


Figure 2 Vibration spectra of power tools selected in this study.

2.3 Test procedure

Three types of VR gloves were prepared in this study. Among these three types, glove1 and 2 were certified as anti-vibration gloves that were satisfied with the ISO 10819 (2013) and JIS T8114 (2007) [5] test requirement. JIS T8114 (2007) is the domestic standard of the anti-vibration test protocol which is identical to a previous version of ISO 10819 (1996).

Each subject with the adapter inserted between a test glove and the palm in the right hand, grasped an experimental handle secured at a one-axis hand-arm vibration test rig. The subjects were asked to stand upright on the force plate. In grasping the handle, the subjects were advised to keep the forearm horizontally and to bend their elbows with an angle of 90±10 degrees, not to touch the arm to their body during the measurement. At this posture the subjects were exposed to HAV in the Zh direction. Also the subjects were advised to control the gripping and feed forces to 30±5 N and 50±8 N, respectively through a monitor that displays the real-time magnitudes of these forces.

Firstly each subject put on the VR-gloves in the right hand and was then exposed to the extended ISO test vibration to obtain acceleration data at the handle and at the palm adapter. Transfer functions of the VR-gloves were calculated on the basis of the method reported by a previous study [4] using the obtained acceleration data at the handle and at the palm adapter. Secondly each subject with the VR-gloves was exposed to the tool vibrations to obtain response acceleration data at the handle and at the palm adapter.

3. Results

Figure 3 shows the vibration transmissibility of gloves measured for the extended test vibration signal. Each glove transmissibility curve showed marked peaks at 100 Hz and around 250-400 Hz. Especially the transmissibility curve of glove 3 showed a steep peak more than 1.0 at 400 Hz. These glove transmissibility curves were used as transfer functions of glove-hand system, respectively.

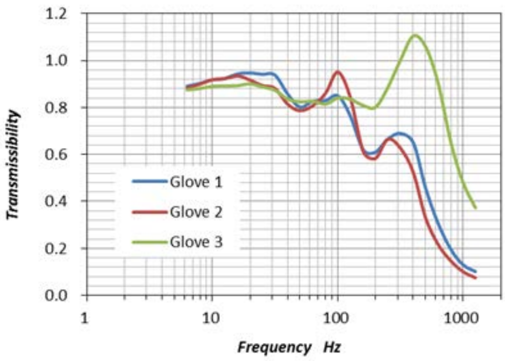
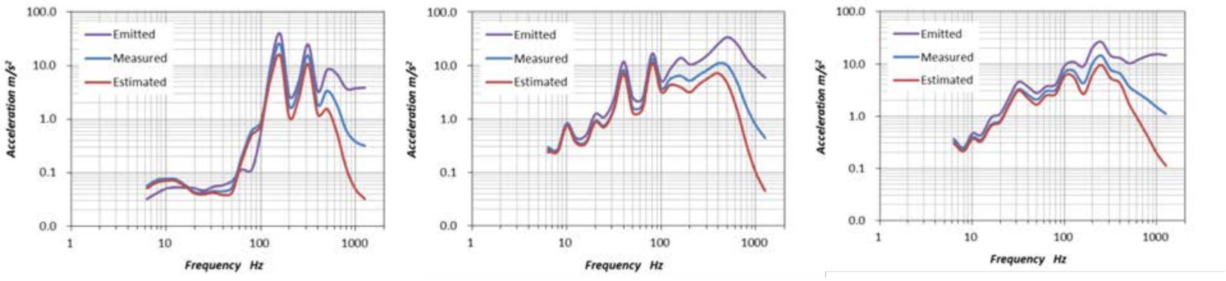


Figure 3 The vibration transmissibility of gloves measured for the extended test vibration signal.

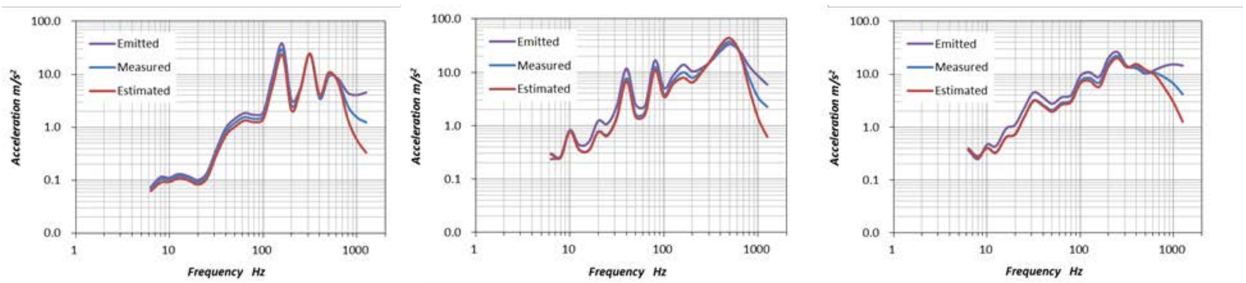
Measured and estimated vibration spectra obtained from glove 1 and 3 tests were shown in Figures 4 and 5, respectively. The measured vibration spectra represent the averaged data of three trials for four subjects. The estimated vibration spectra of gloves 1 and 3 showed relatively good agreements with the measured vibration spectra at a frequency range up to 500 Hz. At frequencies more than 500 Hz, considerable deviations were observed between the estimated and the measured vibration spectra of the gloves.



(a) Random sander (b) Hammer drill (c) Impact wrench

Figure 4 Comparison of measured and estimated accelerations of glove 1.

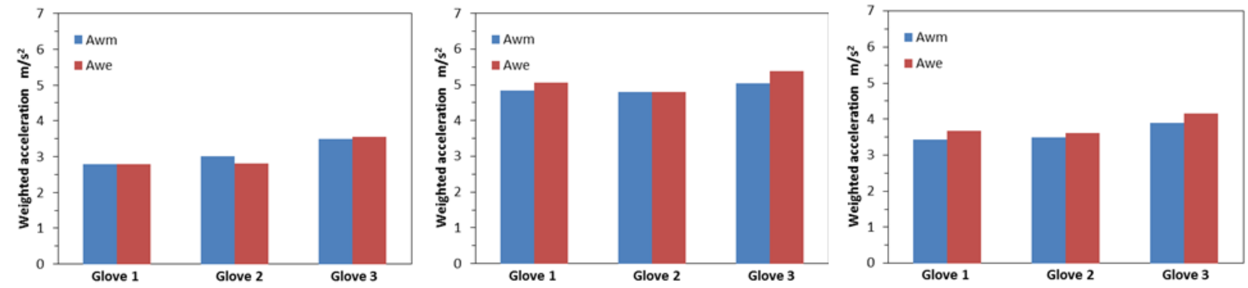
Glove 1 showed amplification for random sander vibration at frequencies up to 16 Hz and at 60 100 Hz. Regardless of tools, glove 2 showed fairly good agreements at frequencies particularly up to 600 Hz between the measured and the estimated vibration spectra compared to glove 1.



(a) Random sander (b) Hammer drill (c) Impact wrench

Figure 5 Comparison of measured and estimated accelerations of glove 3.

As shown in Figure 6, the estimated overall weighted accelerations (6.3-1,250 Hz) for tool vibrations were compared with the measured one. The estimated overall accelerations calculated at 6.3-1,250 Hz showed good agreements with the measured overall accelerations. Regardless of the glove types, the errors between the estimated and measured overall weighted accelerations were less than 7.5 % for all the tool vibrations. Except for the estimated overall weighted acceleration for random sander in glove 2, all the estimated accelerations were a bit larger than the measured one.



(a) Random sander (b) Hammer drill (c) Impact wrench

Figure 6 Comparison of the measured and estimated overall weighted accelerations for tool specific vibrations. (Awm (m/s2): measured, Awe(m/s2):estimated)

4. Discussion

The overall weighted accelerations for tool-specific vibrations were obtained within the tolerant error of 7.5%. Moreover the estimated overall weighted accelerations obtained in this study were larger than the measured ones, which means that the overall weighted accelerations were estimated in safety side.

If the vibration transmissibility of VR-gloves is measured on the basis of ISO 10819 test protocol with the extended test vibration signal, HAV dose level of the gloved hand can be estimated. Despite of the estimation for limited power tools, our results suggest that HAV dose level of tool operators in real workplaces ca be quantitatively controlled and reduced by the use of VR-gloves. This method can be easily applied to the evaluation of vibration transmissibility of gloves in the finger side. Because of the anatomical structure of the human hand fingers, the glove in the finger side cannot effectively attenuate the transmitted vibration. A future study will include the control of vibration transmissibility in the finger side. This methods will be a help for that future study.

5. Conclusion

In this study vibration-isolating performance of vibration-reducing gloves for real tool vibration signals was predicted by using the transfer function method. The overall weighted acceleration values of the gloved hand could be estimated for too-specific vibrations within a tolerable error.

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