

MEASUREMENT OF HAND-TRANSMITTED VIBRATION EXPOSURES

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Introduction

The magnitude of hand-transmitted vibration (HTV) and the exposure duration are the essential factors to be considered in the risk assessment of HTV exposure (ISO 5349-1, 2001). Technical guidance for the measurement of HTV can be found in ISO 5349-2 (2001). The requirements of the instrumentation are documented in ISO/DIS 8041 (2003). While the measurement of many powered hand tools (such as chipping hammers, rock drills, and jackhammers) remains a very challenging task, the exposure duration has been estimated mostly based on workers' claims. This paper outlines the major methods, instrumentation, practices, and pitfalls of the HTV exposure measurement.

Measurement of Vibration

ISO 5348 recommends that the fundamental resonant frequency of the accelerometer to be used for the vibration measurement should be more than five times the maximum frequency of concern. For HTV exposure, it is required to measure the vibration up to 1,250 Hz (1/3 octave-band center frequency) (ISO 5349-1, 2001). This means that the fundamental resonant frequency of the accelerometers should be greater than 7,000 Hz. For this reason, piezoelectric accelerometers are most frequently used in the HTV measurement. Installing accelerometers on a tool or a vibrating work piece may change its mechanical structure and properties, and thus affect its vibration characteristics. To minimize this effect, it is recommended that the mass of the accelerometers and their mounting systems should be less than 5% of the mass of the tool or the working piece (ISO 5349-2, 2001). Vibration in three orthogonal axes defined in ISO 5349-1 (2001) should be measured. The accelerometers should be installed on the tool or work piece at locations as close as possible to the hand's grasping positions. The recommended mounting locations on typical tools and the mounting methods are described in ISO 5349-2 (2001).

A Major Problem: DC-Shift

Directly exposing many piezoelectric accelerometers to moderate or severe shocks, such as occurs on many percussive tools, can cause a DC-shift (the resting output varying after each shock). The DC-shift can result in an erroneous spectrum in a large frequency range (e.g. up to 200 Hz was reported by Kitchener, 1977). The vibration components in this frequency range usually compose more than 90% of the weighted acceleration value because the current weight at frequencies higher than 200 Hz is very small (ISO 5349-1, 2001). Hence, the DC-shift could result in a substantial overestimation of the vibration magnitude. It is extremely difficult to eliminate the DC shift but it can be reduced to an acceptable level (e.g. $< 2 \text{ m/s}^2$ at 10 Hz on a chipping hammer handle) by selecting an appropriate accelerometer and using a mechanical filter in its mounting on a tool. A laser vibrometer can be used to accurately evaluate the DC-shift (Dong et al., 2004). The characteristics of the DC-shift in a time history can also be used to help determine the validity of the vibration measurement (Griffin, 1990). There are several simpler and more practical methods for assessing the DC-shift and/or its effect. The first method is to calculate the displacement of the vibration component at the low frequencies from the measured acceleration if the vibration spectrum is available or the vibration at a specific low frequency can be determined (ISO 5349-2, 2001). The calculated displacement is compared with the observed displacement to determine whether the measurement is realistic. The second method is to use the on-the-hand method to measure the tool vibration (Tokita and Ohkuma, 1990; Dong et al., 2003). Human hands can usually effectively absorb or isolate the high frequency vibration components and eliminate the DC-shift in the accelerometer. The vibration transmissibility at the hand back is usually near unity at frequencies less than 150 Hz. The dominant

vibration frequencies of the percussive or impact tools are usually less than 60 Hz. Therefore, the weighted accelerations measured on these tools should not be very different from those measured using the on-the-hand method. The third method is to use an anti-vibration glove in the vibration measurement. A tri-axial accelerometer or a palm adapter equipped with the accelerometer can be held in the palm of the hand wearing the glove (Dong et al., 2002). The glove cannot significantly isolate the low frequency components (<20 Hz) but it can usually effectively reduce the high frequency components and minimize the DC-shift. In the experiment, one should not push on the tool too hard, which may bottom out the glove and cause the DC-shift in the accelerometer held at the palm (Dong et al., 2003). If the low frequency components measured with the accelerometer at the palm are significantly lower than those recorded on the tool, there is likely a DC-shift in the accelerometer mounted on the tool.

Measurement devices

Many commercial devices are available for the vibration measurement. Multi-channel instruments that can perform frequency analyses are the best for the measurement. However, such instruments can be expensive and inconvenient to use at workplaces. For field applications, it is preferred to have a portable device that can directly provide the weighted acceleration value. A caution in the use of such a device is that the device cannot tell you whether the acceleration signal is valid, which may be critical for the measurement on percussive tools. The above-mentioned on-the-hand method and the glove method can be used to help assess the validity of the measurement. The best anti-vibration gloves currently available on the market can usually reduce the weighted acceleration on percussive tools only by less than 30% (Griffin, 1998; Dong et al., 2002; 2003). If the difference between the weighted accelerations simultaneously measured on the tool and inside the glove at the palm would be significantly more than 30%, one should seriously doubt whether the measurements are valid.

Measurement of exposure duration

The exposure duration estimated from workers' claims may not be reliable. Videotaping or on-site observation can provide an accurate measure. This approach, however, could be demanding on the human resources. Acoustic data loggers may also be employed for the measurement. This approach, however, may pose difficulties in isolating the tool-generated noise signal from those arising from other sources in the workplaces. Several other alternative methods are under development (Dong et al., 2001; Maeda, 2004).

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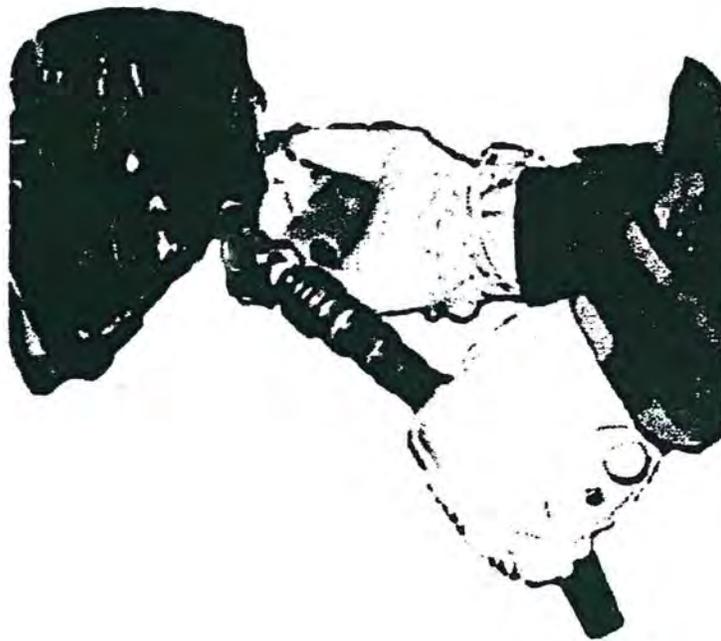
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