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Editorial

Workshop–ISO Development of Standards Relating to Hand-Transmitted Shock †

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1. Introduction

The risk estimation for hand–arm vibration injury is based on ISO 5349-1 [1]. The scope of the 2001 revision of those ISO standards notes that "the time dependency for human response to repeated shocks is not fully known", and the application of ISO 5349-1 to such vibration is to be "made with caution". The covered frequency span is also clearly stated in "The values obtained can be used to predict adverse effects of hand-transmitted vibration over the frequency range covered by the octave bands from 8 Hz to 1000 Hz".

Despite the lack of knowledge in this field, it is still desirable to standardise methods for evaluating hand-transmitted shock vibrations from hand-held and hand-guided machinery. To this end, work is being carried out in ISO Technical Committee 108 to develop guidance for evaluating hand-transmitted shock (HTS) and high-frequency vibration exceeding 1250 Hz, also referred to as "ultravibration" (UV). One driver for this work is a proposed revision to EU Directive 2006/42/EC [2] on Machinery, which would require a declaration of the peak amplitude of the acceleration from repeated shock vibrations.

The revision to the Machinery Directive 2006/42/EC was adopted by the European Commission on 22 May 2023. It will be published in June 2023. Member states will then have 42 months to implement the new Directive, at which time machine manufacturers and suppliers into the EU market will need to declare values for the peak amplitude of the acceleration from repeated shock vibrations.

The objective of the ISO work on shock is to:

- Enhance research on the health effects of HTS;
- Provide machine manufacturers and users a method for evaluating hand-transmitted shock;
- Encourage and enable the following:
  - Machine producers to reduce hand-transmitted shock;
  - The development of mitigation measures on existing tools;
  - The reduction in hand-transmitted shock and vibration exposures in the workplace.

2. Measurement Challenges

2.1. ISO/TS 15694

An existing ISO Technical Specification from 2004 defines several potential measurement parameters for HTS. Unfortunately, no single parameter is recommended, and no parameter has become the de facto standard for measuring hand-transmitted shock and vibration. ISO/TS 15694 [3] uses both Wh-frequency-weighted parameters and flat-h-weighted parameters, using the band-pass component of the Wh weighting, which includes frequencies from 5 to 1250 Hz.

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2.2. Frequency Range or Weighting

Many machines generate continuous vibration at high frequencies—dental drills are often cited in this category, as they operate at rotational speeds of 180,000 to 400,000 rpm (equivalent to 3 to 6.7 kHz). Many other machines generate shock vibrations that include frequency components up to 10,000 Hz and beyond.

Frequencies much higher than 1250 Hz may contribute to the perception of and any health impact of HTS. For this reason, experts are debating what the measurement frequency range should be.

2.3. Maximum (Peak) Vibration Value

A simple measure of HTS would be a maximum peak of the vibration, such that the peak amplitude of hand-transmitted acceleration a_f, measured with an upper-frequency limit of f Hz, defined for any specified time interval $0 \leq t \leq T$, as

$$a_{f,peak} = \left(\left| a_f(t) \right| \right) .$$

The value of the frequency range f will need to be defined for different applications.

2.4. Mean of the Maximum Vibration Values

There are concerns that measurements of single peak values are often very variable in magnitude, so an average peak value has been considered (and the revision of EU Directive 2006/42/EC on Machinery asks for "the mean value of the peak amplitude"). However, to measure an average peak value, the measurement system needs to automatically provide a value for the maximum value for each shock event rather than picking up individual peaks within those events. Unfortunately, this type of measurement is complex, particularly when a shock event consists of a set of multiple peaks. And the complications are greater when the repetition rate is short or the shock's duration is long.

It is worth noting that the equivalent measure for noise exposure is the maximum peak sound pressure level. The variability of peak noise levels is not so apparent because the decibel is used for reporting noise levels.

2.5. Shock Indicator

The crest factor has been used in whole-body vibration as an indicator of the extent to which a vibration signal contains shock and whether specific shock measurements should be made [4].

It is debatable whether there is a need for a similar parameter for hand-transmitted shock; however, where declaration is required for machines generating HTS, there needs to be a means to define a cut-off point for declaration. Repetition rate is a possible indicator, where declaration is only required for isolated HTS. However, isolated HTS is subjective and is dependent not just on repetition rate but also on factors such as the decay rate of the shock. A definition based on repetition rate might also create anomalies, such that similar machines with marginally lower repetition rates do not need the shock magnitude reporting.

3. Proposed Measurement Parameters

An alternative parameter is being considered as an indicator of likely peak value; this is the vibration peak magnitude (VPM) of the acceleration, as defined by

$$VPM_f = \sqrt{\frac{\sum_{i=1}^{i=N} a_f^6}{\sum_{i=1}^{i=N} a_f^4}} \quad (1)$$

It has been shown that the *VPM* gives a value that is representative of typical peak magnitudes in any vibration signal [5]. And the *VPM* has the advantage that it can be derived from continuous measurements.

A possible indicator of whether shock needs to be reported is the vibration shock index *VSI*, given by

$$VSI_f = \frac{VPM_f}{a_{rms,f}} \sqrt{\frac{3}{5}} \tag{2}$$

The *VSI* is a dimensionless parameter, equal to 1 for a sinusoidal signal and increasing for signals containing shocks. As with the *VPM*, the *VSI* will be dependent upon the upper frequency of measurement, f. A *VSI* greater than a value of about 7 suggests that shock is significant and should be reported.

4. Reporting

Information on the peak value of acceleration should be provided alongside information gathered in accordance with ISO 5349-1, plus some additional information relating specifically to the HTS characteristics:

- The root-mean-square value of W_{h}-weighted acceleration, a_{hv} (from ISO 5349-1);
- The dominant direction of HTS in relation to the measurement axes;
- The definition of the frequency limits used for a_f and VPM_f;
- The root-mean-square value of acceleration for each axis, a_f;
- The vibration peak magnitude, VPM_f.

For isolated shocks, the following should also be provided:

- Repetition rate (R) or mean repetition rate ($\bar{R}$);
- Number of shocks per day or per task;
- Either:

  The number of shock events in the measurement and the measurement period;
  The root-mean-square value of W_{hFlat}-weighted acceleration normalised to 3 s.

5. ISO HAV Working Group Activity

The hand–arm vibration working group of ISO Technical Committee 108, Sub-Committee 4, has been working on the development of two new Technical Specifications related to HTS and high-frequency hand–arm vibration. Both were planned as new sub-parts to the ISO 5349 set of standards.

ISO 5349-3 was proposed to deal with the measurement of HTS for frequencies up to the upper limit of the existing hand-am vibration frequency range, i.e., 1250 Hz. Such a standard would provide measurements of isolated and repetitive shock that could be carried out with existing instrumentation that conforms to ISO 8041-1 [6].

ISO 5349-4 was proposed to expand the frequency range for all forms of hand–arm vibration measurement, with a focus on the high-frequency content of many HTS signals. The peak amplitude of shocks and other magnitude measurements can be very dependent upon the chosen upper-frequency filter frequency and characteristics. The specification does not specify a single frequency range of measurement. Instead, it recommends some preferred upper frequencies that can be selected and must be reported with the vibration data.

The overlapping objectives of the two proposed standards have been problematic, and recent discussions have led to the ISO working group reviewing our original plans for two separate standards. Alternative options are being considered. One is to have a single standard that provides definitions, such as those shown here as Equations (1) and (2), that can be adapted for different frequency ranges—for example, $VPM_{1250\mathrm{Hz}}$ would provide the data for ISO 5349-3, but other frequency ranges planned for ISO 5349-4 are allowed, such as $VPM_{10\mathrm{kHz}}$.

Feedback from the Nancy Workshop will inform future progress in the working group.

6. Conclusions

New standards on the measurement of HTS will represent significant developments in hand–arm vibration standards. The objective is for a standard that has a clear definition of a single shock parameter and can be applied to the declaration of vibration emissions and assessments of hand–arm vibration exposures.

The use of such standards will contribute to the gathering of consistent HTS data to improve occupational safety. It is hoped that the HTS data gathered will contribute to developing an understanding of the link between exposure to HTS and health effects on the hand and arm.

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References

1. *ISO 5349-1:2001*; Mechanical Vibration—Measurement and Evaluation of Human Exposure to Hand-Transmitted Vibration—Part 1: General Requirements. International Organization for Standardization: Geneva, Switzerland, 2001.
2. European Union. *Directive 2006/42/EC of the European Parliament and of the Council of 17 May 2006 on Machinery, and Amending Directive 95/16/EC (Recast)*; European Union: Maastricht, The Netherlands, 2006.
3. *ISO/TS 15694:2004*; Mechanical Vibration and Shock—Measurement and Evaluation of Single Shocks Transmitted from Hand-Held and Hand-Guided Machines to the Hand-Arm System. International Organization for Standardization: Geneva, Switzerland, 2004.
4. *ISO 2631-1:1997*; Mechanical Vibration and Shock—Evaluation of Human Exposure to Whole-Body Vibration—Part 1: General Requirements. International Organization for Standardization: Geneva, Switzerland, 1997.
5. Lindell, H.; Johannisson, P.; Grétarsson, S.L. Definition and quantification of shock/peak/transient vibration. In Proceedings of the 15th International Conference on Hand-Arm Vibration, Nancy, France, 6–9 June 2023. [CrossRef]
6. *ISO 8041-1:2017*; Human Response to Vibration—Measuring Instrumentation—Part 1: General Purpose Vibration Meters. International Organization for Standardization: Geneva, Switzerland, 2017.