

Uncertainty in measurement

By Martin Armstrong MIOA, Alcor S&V

This article is in the continuing series of Instrumentation Corner, from the members of the Measurement and Instrumentation Group committee. Here the measurement is in the spotlight when reporting an evaluation, not so much the instrument where the uncertainties are small.

Why measure sound and vibration? Is it to evaluate machinery for the purposes of design, or for condition monitoring, or is it to protect humans from annoyance or harmful physical effects. In each case it is likely that some limit has to be set to evaluate the risk. Is the aim to comply with such a directive as the Control of Vibration at Work Regulation 2005, SI No 1093?

How well does a measured magnitude correlate with the magnitude of sound or vibration at the point of measurement? What are the uncertainties that need to be considered? How well can they be tabulated? How rigorous does an uncertainty budget need to be? Or have the required action and limit magnitudes been set so as to accommodate the expected upper uncertainty band for a measurement?

An apology to those acousticians not involved in vibration, for my use of 'value' for a measurement. I shall use the term value, mainly because my background is in vibration, but please take it as also including level.

Uncertainty evaluation raises many questions, as can be seen above. In any measurement there will always be a certain degree of uncertainty associated with the instrument, the location of the transducer, source variation and duration of measurement. In quantifying measurement uncertainty the IOA Diploma module has a section in the General Principles of Acoustics. There is not a comparable one specifically covering vibration. Many of the quantities that need to be addressed apply to both sound and vibration. The causes of measurement uncertainty can be split into two headings, random or systemic.

A new policy is being implemented in the testing of instruments, such as for Sound Level Meter BS EN 61672 and Human Response to Vibration Meter BS ISO 8041. Tolerance limits around design goals can be determined from the specified acceptance limits for allowed deviations, from a design goal, and the corresponding specified maximum permitted uncertainty of measurement. See the illustration below showing the acceptance interval.

U_{\max} Guard band maximum permitted measurement uncer-

tainty, 95% coverage interval.

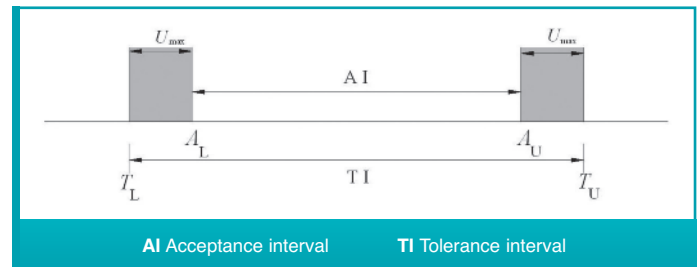
Considering the measurement uncertainty, for the Human Response to Vibration Meter BS EN ISO 8041 for HA assessment, the following component uncertainties need to be included. The display, frequency weighting, amplitude linearity, transverse motion, phase response and transducer mounting, to mention a few. A suggested expanded total measurement uncertainty is shown below, where at the reference frequency it is 7.5%.

There are two guidance documents that are useful in ensuring the best evaluation of HA vibration. BS EN ISO 5349-2 covers the measurement and evaluation of human exposure to hand-transmitted vibration. PD CEN/TR 15350 covers the assessment of exposure to hand-transmitted vibration using available information including that provided by manufacturers of machinery with the estimated exposure times. Each of these refer to the use of test code standards, the first with respect to transducer location and repeat tests and the other to the declared emission value including uncertainty K value from a test code.

How well can these work in practice? Using BS EN ISO 5349-2 the requirement is to measure and then evaluate a wide range of uncertainties. Uncertainties associated with the instrument, covering the weighting, calibration and transducer mounting are considered systemic and are small, as shown above. Uncertainty factors of measurement may be due to machine operator variability and the skill of the worker, the repeatability of the work task and variation of measurement location. The uncertainty of the overall evaluation of the exposure depends on the uncertainty of the established vibration value and its ability to represent the actual vibration total value. It also depends on the uncertainty of the exposure duration.

Even where the vibration magnitude and exposure times are measured, as in BS EN ISO 5349-2, the uncertainties associated with the evaluation of $A(8)$ can mean that the calculated value can be as much as 20% above the true value to 40% below. There is no suggested uncertainty budget identifying the components influencing the total uncertainty.

Should a vibration measurement not be considered necessary then PD CEN/TR 15350, Guideline for the assessment of ▶



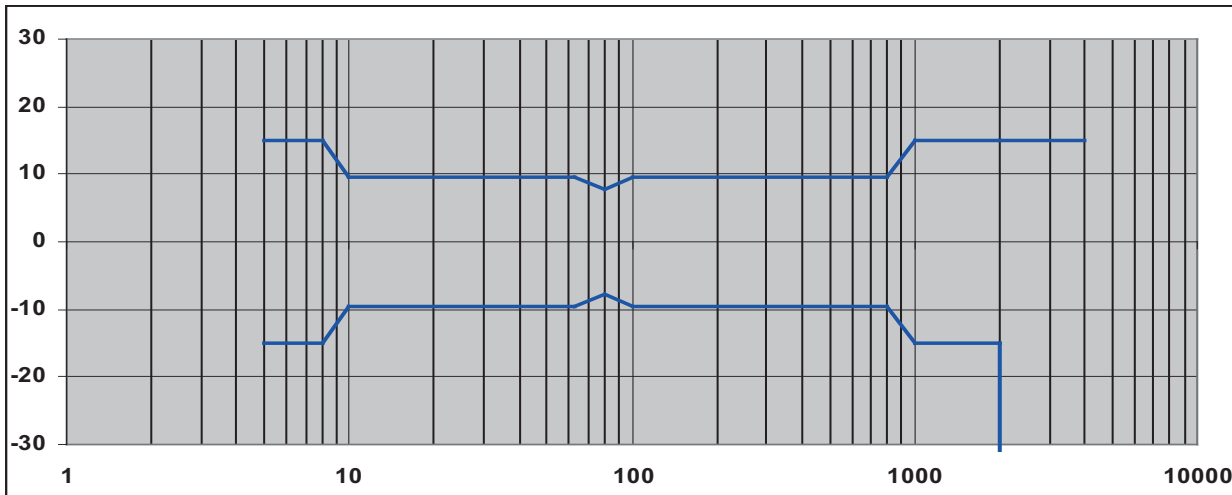
exposure to hand-transmitted vibration using available information including that provided by manufacturers of machinery, can be used. This standard addresses the manufacturers declared values and uncertainty K. In some cases the K value can be 40% of the stated vibration value. Four groups of test codes are covered, these are electric, pneumatic, hydraulic and internal combustion engine machines. For each group, and the individual types, multiplying factors are given. The multiplying factors can be up to x2, (+100%). The uncertainty of the vibration value has more influence on the uncertainty of the daily vibration exposure than that of the exposure duration, because the vibration exposure is proportional to the vibration value and to the square root of the

exposure duration.

When completing any investigation, it being vibration or acoustic, the report showing any risk should document all corrections and uncertainties that have been taken into account. These may show +40%, +60% or +100% corrections to a measured value.

Please note that the standards referred to in this article are current. However they are each undergoing revision in part, with amendments, or more extensively.

Martin Armstrong is a founder member of the Measurement & Instrumentation Group and is the current secretary. Martin is on several BS and ISO working groups standardising vibration instrumentation.



Expanded total measurement uncertainty %; 95% confidence (K=2)