

Instrumentation Corner

Richard Tyler. Uncertainty of vibration measurements

Uncertainty arises from all measured sources. An absolute unit of acceleration that can be checked for perfection does not exist. The measurements that define any quantity have a small degree of possible error that can usually be expressed in terms of a small fraction of the unit under consideration. For most of the parameters associated with vibration measuring instrumentation, the errors are finite and the estimate of their magnitude can be made under fairly closely controlled conditions.

Note that when assessing measurements against the values in the Physical Agents (Vibration) Directive (PA(V)D), the actual measured levels **plus** their associated uncertainty of measurement **must** be less than the exposure limit values (ELV)

The list below shows typical values for some of the more common uncertainty terms that affect vibration measuring instruments.

- Reference accelerometers: typically 0.7%, and 2% at higher frequencies
- Accelerometers in daily use: 3% to 5%
- Voltmeter: 0.25% for AC volts
- Frequency counter: negligible

The number which is impossible to quote reliably in the above list is that associated with the mounting of the transducer. An allowance of 10% to cover the location and fit is probably a reasonable starting point.

Any uncertainty calculation must consider the following elements.

- Mounting of the transducers
- Location and orientation of the transducers
- Changes from the normal operation caused by the introduction of the transducers
- Changes in the machine condition during measurement
- Changes in the operator's working conditions during measurement, eg a vehicle on rough or smooth ground
- Errors in the duration of work cycles
- Errors in the number of work cycles per day
- Variability in the work patterns over different days
- Errors in the measuring instrumentation.

As nobody usually knows the limit of uncertainty, it is usually calculated from formulae which define uncertainty with respect to a degree of confidence. The most common value used is 95%, and as an

approximate rule, the uncertainty calculation is multiplied by 2 to give 'the expanded uncertainty with a confidence level of 95%'.

The uncertainties associated with the accuracy of the measuring equipment are usually dwarfed by those associated with trying to measure the vibration source. The effects of people on the vibration source can cause very large variations in the vibration transmitted to the person.

The positioning of transducers can cause significant differences between the measured level and the actual levels received by the person, and the quality of transducer attachment can impact on the measured values. Attempting to put figures to the uncertainty of these items is fraught with difficulty. A suggested range of values is given in Table 1.

Examples of instrument accuracy

The National Measurement System of the DTI (as it was then) funded experimental work to investigate uncertainty of measurement in the instrumentation of human exposure to vibration. This work used a range of commercial instrumentation systems to measure hand-arm and whole body exposure in controlled yet realistic environments.

Individual measuring systems returned consistent and repeatable measures of vibration amplitude, well within the uncertainties suggested in the table. Weighted acceleration results were distributed with a worst-case ratio of standard deviation to mean of 6.6%. This distribution was caused by the consequences of removing and replacing the accelerometer, rather than the intrinsic accuracy of the instrumentation system itself. In repeat measurements involving no such repositioning of the transducer, the repeatability was <1.5%.

Further information

Tyler, Richard: *Good Practice Guide on the use of instrumentation to measure vibration affecting people*. Published by the Institute of Acoustics, St Albans 2004

Bell, Stephanie A *beginner's guide to uncertainty of measurement*. Measurement good practice guide no.11. National Physical Laboratory, London 1999

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Parameter	Uncertainty	Estimate of typical uncertainty, % best practice
Instrumentation		
Accelerometer calibration (at reference)	±3%	±3%
Accelerometer frequency response	±2.5%	+2.5, -0
Instrumentation	±4%	±4%
Measurement process		
Measurement duration	+10/ -0%	+10, -0
Triboelectric effect	negligible	±2%
Electrical pickup	negligible	±2
Mounting: rigid	negligible	±2
Mounting: hand-held	+100/ -50%	-
Mass of transducer(s)	negligible	±2%
Transverse response (with or without mechanical filters)	+4/ -0%	+4, -0
Location of transducer	+100/ -50%	±15
Exposure time measurement		
Video monitoring	negligible	±2
Number of components from production records	~±10%	±10
Number of components by video	~±2%	±4
Active sampling	variable	±10

Table 1

Indicative uncertainty values