DETERMINING THE MEASUREMENT UNCERTAINTY OF WORKPLACE MEASUREMENTS CONFORMING TO GUM

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Introduction

For an assessment of the reliability of measurement results, it is essential that measurements are correctly performed and that the measurement uncertainty is known. To obtain information on the quality of the measurement results from different laboratories, knowledge of the measurement uncertainty is required even in the case of standardised and "error-free" measurements. This becomes increasingly important when measured data are supplied to databases from different sources. More precise calculations of the measurement uncertainty are also required for the validation of hazard analyses and for vibration reduction forecasts and programmes.

A uniform guide for different measurement quantities has been available for 20 years in the shape of the Guide to the Expression of Uncertainty in Measurement (GUM) [1]. Since it has not so far been applied to the field of human vibration exposure owing to the unacceptably high complexity of the task, DIN SPEC 45660-2 [2] has been produced in Germany.

This technical report contains examples of the measurement uncertainty of vibration exposure calculated from activity-related measurements to ISO 5349-2 [3]. The guide values of the measurement uncertainty contributions used are based among other things on an interlaboratory test organised by IFA. The goal of the test was to determine the measurement uncertainty for standardised measurements.

Methods

To ensure the same conditions for the duration of the interlaboratory test, a fictitious workplace was set up for three tasks to be performed by two experienced workers. The tasks consisted of cutting square tubes with a pneumatic angle grinder, drilling dowel holes with an electric rotary hammer and cutting contours in glulam worktops with an electric jig saw (see Fig. 1).

Fig. 1: Measurement tasks

Seven laboratories accredited to ISO/IEC 17025 [4] took part in the interlaboratory test. Each laboratory carried out its measurements independently on a separate day. To ensure uniformity, new tools and materials were used on each day of measurement and the proceedings were monitored by an independent observer. To compare the series of measurements, additional control tasks were carried out with a calibrator for three fixed frequencies and amplitudes.

Results and Discussions

Each laboratory evaluated its own data and conducted a risk assessment. All the data were evaluated by the neutral Institute for Proficiency Tests (IfEP) in conformity with ISO/IEC 17043 [5], ISO 13528 [6] and ISO 5725-2 [7].

The calculation model for measurement uncertainty to DIN SPEC 45660-2 [2] is based on the main uncertainty contributions presented in Table 1. The laboratory standard deviation u_M is obtained with the following equation:

$$u_M = \sqrt{u^2_{Measuring\ instrument} + u^2_{Coupling} + u^2_{Sensor\ position}}$$

To validate the calculation model conforming to DIN SPEC 45660, the measurement uncertainties of the respective overall vibration values are calculated in accordance with EUROLAB TR 1/2006 [8] and compared. The results from the two models were largely identical, although the EUROLAB model tended to show higher values. In addition, the trueness and precision of all measurement results were determined and the reproducibility, repeatability and laboratory standard uncertainty were calculated.

Components of the measurement uncertainty			Relative uncertainty (orientation values)									
			Rotary hammers (Span length)		Chain saws (Span length)		Rotary hammers*)		Jig saws*)		Grinders*)	
i	$u(x_i)$	$u_M = u_{(x_1,x_2,x_3)}$	Range (±) %	$u(x_i)$	Range (±) %	u_c	(±) %	u_M	(±) %	u_M	(±) %	u_M
1	Measuring instrument for[3*)]: Laboratory application Field application	Measuring point standard deviation u_M	8,2 - 13 12,6 - 26	0,075 0,152	17 to 33	0,098 to 0,191	21,3	0,123	16,1	0,093	54,0	0,312
2	Sensor coupling (without mechanical filter)		5	0,029								
3	Sensor position (measuring point)		30	0,173								
4	Repeatability standard deviation of a test subject (user)		(8)	(0,046)			(Method A) $u_{(x4)a}$					
5	Test subject standard deviation		15	0,087								
6	Production standard deviation (product dispersion)		8	0,046								

*) Results of the interlaboratory test (round robin test)

Table1: Orientation values of the measurement uncertainty contributions DIN SPEC 45660

The inaccuracy data of all the measuring instruments are based on the supplements to measuring instrumentation standard ISO 8041 [9].

References

1. ENV 13005 Guide to the expression of uncertainty in measurement GUM
2. DIN SPEC 45660-2 Guide for dealing with uncertainty in acoustics and vibration – Part 2: Uncertainty of vibration quantities
3. ISO 5349-2(2001) Mechanical vibration - Measurement and evaluation of human exposure to hand-transmitted vibration - Part 1: General requirements, Part 2: Practical guidance for measurement at the workplace
4. ISO/IEC 17025(2005) General requirements for the competence of testing and calibration laboratories
5. ISO/IEC 17043(2010) Conformity assessment - General requirements for proficiency testing
6. ISO 13528(2005) Statistical methods for use in proficiency testing by interlaboratory comparisons
7. ISO 5725-2(1994) Accuracy (trueness and precision) of measurement methods and results - Part 2: Basic method for the determination of repeatability and reproducibility of a standard measurement method
8. EUROLAB Technical Reports 1/2006, Guide to the Evaluation of Measurement Uncertainty for Quantitative Test Results
9. ISO 8041 Human response to vibration - Measuring instrumentation, Amendment (2015)

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