Technical Information

Measurement Uncertainty for Leeb Hardness Tests

***“In every measurement even the most carefully performed, there is always a margin of doubt.”* Measurement uncertainty analysis is applied to understand differences in test results and to determine sources of error. The uncertainty of a Leeb hardness measurement system consists of a statistical component, a component inherent to the measurement device and a component arising from the metrological chain between national standard and the user device (traceability).**

Symbols

Applying the denominations from DIN 50156, commonly used symbols in Leeb hardness uncertainty are as follows:

u_{HTM}; U_{HTM}	uncertainty of hardness testing machine ($k = 1$ / $k = 2$)	n	number of measurements
u_X	uncertainty due to in-homogeneity of test piece	k	coverage factor
u_E	uncertainty due to maximum permissible error	s_X	standard deviation
u_{ms}	standard uncertainty due to resolution of measuring system	t	Student’s factor
U_C	combined measurement uncertainty ($k = 2$)		

Applicable Standards

The reader shall refer to DIN 50156-1 and ISO/FDIS 16859-1 for detailed instructions to calculate Leeb measurement uncertainties.

Expressing Uncertainties of Measurement

We might say that the hardness value of a test block measures **780 HLD ± 6 HLD**, where ± 6 HLD is the uncertainty. **With $k = 2$, the statement implies we are 95% certain that the test block hardness is between 774 HLD and 786 HLD.**

Combined Uncertainty

The uncertainty of an Equotip hardness tester and the hardness test block can be found on the calibration certificates of the Equotip impact device and of the test block, respectively.

The standard DIN 50156-1, e.g., provides two methods M1 and M2 to calculate the uncertainty for a hardness measurement conducted by the user on a test piece.

Here is an example of measurement using method M2:

1. The calibration certificate of an Equotip impact device D may read U_{HTM} ($k = 2$) = 5.8 HLD for the expanded uncertainty, with a combined uncertainty value of u_{HTM} ($k = 1$) = 2.9 HLD.

2. A series of 10 readings taken on a test piece (e.g. steel roll, motor block) are assumed to **average as 780.2 HLD** with a standard deviation of s_X = 2.2 HLD, therefore the uncertainty will be as follow:

$$u_x = \frac{t \, * \, sX}{\sqrt{n}} = \frac{1.09 * 2.2}{\sqrt{10}} = 0.076\,HLD$$

3. For a test on the sample of ~780 HLD, first the maximum permissible error of the bias is calculated where a factor of 1/2.8 is used to account for the case of the standard uncertainty of a rectangular distribution.

Hardness of test block	**Maximum permissible error of tester**
≤ 450 HL	±4.0%
450-750 HL	±3.0%
≥750 HL	±2.0%

$$u_E = \frac{0.02 \, * 780\,HLD}{2.8} = 5.6\,HLD$$

To find the combined uncertainty of the measurement with a given Equotip impact device on a test piece, we need to calculate the geometric mean as follow:

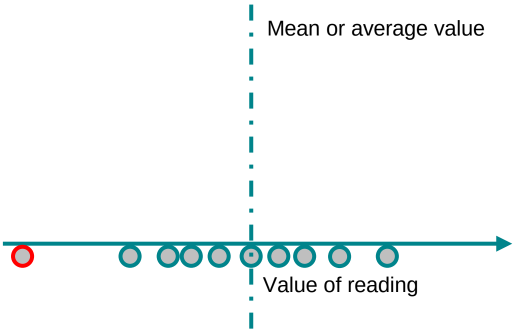
$$U_C(k=2) = 2\sqrt{u_{HTM}^2 + u_X^2 + u_E^2} = 2\sqrt{2.9 + 0.76 + 5.6}\ \text{HLD} = 12.7\ \text{HLD}$$

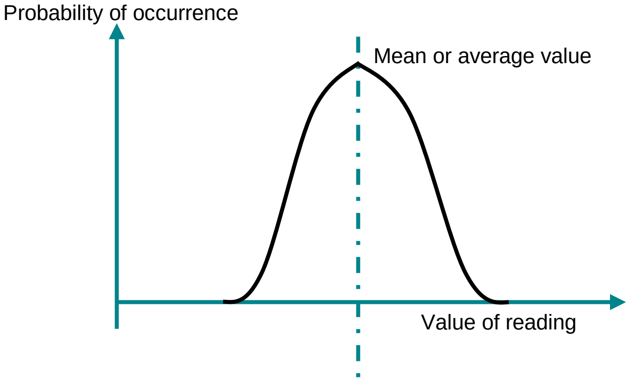
Based on this example, the average hardness of 780.2 HLD of the test piece measured with the given Equotip impact device would hold an uncertainty of 12.7 HLD.

“How many readings should I take?”

When more individual readings are used to obtain the final result, we will be more certain that the calculated average is closer to the actual hardness of the test piece. However performing more measurements could take extra effort and yields with marginal overall improvement on our data.

- As a rule of thumb, **anything between 3 and 10 readings** is generally acceptable unless stated otherwise.
- Taking 10 readings is a common choice as this reduces the statistical uncertainty, averages outlays and makes the arithmetic easy. In some cases taking 3 readings is sufficient, this practice is common where test pieces are comparatively homogeneous in hardness.
- Using 20 or even 50 only give a slightly better estimate than 10.





What Measurement Uncertainty is Not

Statistical analysis is not the same as uncertainty analysis. Statistics are usually used in uncertainty calculations, but can be used to draw conclusions which go beyond the usage for uncertainty calculations.

Accuracy (or rather inaccuracy) is not the same as uncertainty. Correctly speaking, ‘accuracy’ is a qualitative term (e.g. you could say that a measurement was ‘accurate’ or ‘not accurate’). Uncertainty is quantitative. A ‘plus or minus figure’ may be called uncertainty, but not accuracy.

Specifications and tolerances are not uncertainties. While specifications state what can be expected from a product (incl. ‘non-technical’ qualities such as its color), tolerances could be referred to as acceptance limits which are chosen for a process or a system.

Errors are not the same as uncertainties, especially in the past it’s been common to use the words interchangeably. An error usually refers to a malfunction within the system. However, recently also the term ‘error’ has been used synonymously with ‘bias’, which usually is considered as a component of the measurement uncertainty.

Mistakes made by operators are not measurement uncertainties. They should be avoided by working carefully and by double-checking work.