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Calibration and verification of the torque measuring device of torsion testing machines

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Deutscher Kalibrierdienst (DKD) – German Calibration Service

Since its foundation in 1977, the German Calibration Service has brought together calibration laboratories of industrial enterprises, research institutes, technical authorities, inspection and testing institutes. On 3rd May 2011, the German Calibration Service was reestablished as a *technical body* of PTB and accredited laboratories.
This body is known as *Deutscher Kalibrierdienst* (DKD for short) and is under the direction of PTB. The guidelines and guides developed by DKD represent the state of the art in the respective areas of technical expertise and can be used by the *Deutsche Akkreditierungsstelle GmbH* (the German accreditation body – DAkkS) for the accreditation of calibration laboratories.
The accredited calibration laboratories are now accredited and supervised by DAkkS as legal successor to the DKD. They carry out calibrations of measuring instruments and measuring standards for the measurands and measuring ranges defined during accreditation. The calibration certificates issued by these laboratories prove the traceability to national standards as required by the family of standards DIN EN ISO 9000 and DIN EN ISO/IEC 17025.

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* VMPA = Verband der Materialprüfungsanstalten e.V. (Association of Material Testing Institutes)

Foreword

DKD guidelines are application documents that meet the requirements of DIN EN ISO/IEC 17025. The guidelines contain a description of technical, process-related and organizational procedures used by accredited calibration laboratories as a model for defining internal processes and regulations. DKD guidelines may become an essential component of the quality management manuals of calibration laboratories. The implementation of the guidelines promotes equal treatment of the equipment to be calibrated in the various calibration laboratories and improves the continuity and verifiability of the work of the calibration laboratories. Moreover, the implementation of the guidelines helps to ensure that the state of the art in the respective field is taken into account in laboratory practice.

The DKD guidelines should not impede the further development of calibration procedures and processes. Deviations from guidelines as well as new procedures are permitted in agreement with the accreditation body if there are technical reasons to support this action.

Calibrations by accredited laboratories provide the user with the security of reliable measuring results, increase the confidence of customers, enhance competitiveness in the national and international markets, and serve as metrological basis for the monitoring of measuring and test equipment within the framework of quality assurance measures.

This guideline has been drawn up by the DKD Technical Committee *Materials Testing Machines* and the VMPA working group *Testing Machines and Equipment* and approved by the Board of the DKD.

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1 Introduction

This guideline is applicable to the static calibration and verification of torsion testing machines using a procedure based on the calibration of materials testing machines according to DIN EN ISO 7500-1 [1].

The verification implies:

– a general inspection of the torsion testing machine, including the parts used for the application of torque;

– a calibration of the torque measuring device of the torsion testing machine;

– a confirmation that the determined properties of the torsion testing machine meet the limits given for a specified class.

Note: DKD-R 9-1 refers to the static calibration and verification of torque measuring devices. The calibration results are not necessarily valid for high-speed tests or dynamic testing.

Caution: Some of the tests specified in this Guideline involve the use of processes that may lead to a hazardous situation.

This Guideline may also be used for the calibration and verification of indicating devices of testing machines or test rigs using the measurand *torque*, e.g. fastener test benches, brake test benches, etc. This Guideline is not meant for the calibration of measuring instruments such as torque wrenches.

As for the torsion testing machines, a distinction must be made as to whether the test specimen is subjected solely to torque, or whether there is a simultaneous application of force in addition to torque. In the latter case we are dealing with an axial/torsional testing machine. However, when calibrating an axial/torsional testing machine, this Guideline considers it to be only a torsional testing machine. Therefore, the calibration is carried out without applying defined forces. The load path of the axial/torsional testing machine has to be adjusted to zero force at any time throughout the calibration. In this case, the calibration certificate should state that the test system has been calibrated at zero force.

2 Terms, definitions

Symbols

Symbols	Unit	Meaning
a	%	Relative resolution of the torque indicating device of the torsion testing machine with applied torque
a_Z	%	Relative resolution of the torque indicating device of the torsion testing machine in unloaded state with indicated torque t M_i
b	%	Relative repeatability of the torque measuring device of the torsion testing machine
b_{al}	%	Permissible value of b for a given class
E	%	Estimated mean relative deviation from increasing torques
E'	%	Estimated mean relative hysteresis from decreasing torques

f_0	%	Relative zero deviation of the torque measuring device of the torsion testing machine
k		Coverage factor to calculate the expanded uncertainty from the combined uncertainty
M	N·m	Reference torque indicated on the torque transducer with increasing torque
M'	N·m	Reference torque indicated on the torque transducer with decreasing torque
M_c	N·m	Reference torque indicated on the torque measuring device during the additional measurement series in the smallest torque indicating range used, in case of increasing torque
M_i	N·m	Indicated torque on the torque indicating device of the torsion testing machine in case of increasing torque
M_i'	N·m	Torque indicated on the torque indicating device of the torsion testing machine in case of decreasing torque
$\bar{M}_i, \bar{M}$	N	Arithmetic mean values from several measurements of M_i and M with identical torque level
M_{ic}	N·m	Torque indicated on the torsion testing machine during the additional measurement series in the smallest torque measuring range used, in case of increasing torque
M_{i0}	N·m	Residual indication on the torque indicating device of the torsion testing machine to be examined after unloading
M_N	N·m	Maximum value of the calibrated torque indication range of the torsion testing machine
q	%	Mean relative indication error of the torque measuring device of the torsion testing machine
q_i	%	i^{th} measurement of the relative indication error of the torque measuring device of the torsion testing machine
q_{al}	%	Permissible value of q for a given class
q_{auf}	%	Relative indication error of the torque measuring device of the torsion testing machine with increasing torque, corresponding to q_i during the measurement series for determining the hysteresis
q_{ab}	%	Relative indication eror of the torque measuring device of the torsion testing machine in case of decreasing torque
q_c	%	Relative indication error of the torque measuring device of the torsion testing machine when checking the additional equipment
q_{max}	%	Maximum value of q at each calibration point
q_{min}	%	Minimal value of q at each calibration point
q_{T1}	%	Relative indication error determined at an overlap point with torque measuring instrument 1
q_{T2}	%	Relative indication error determined at an overlap point with torque measuring instrument 2
r	N·m	Resolution of the torque indicating device of the torsion testing machine

r_z	N·m	Resolution of the torque indicating device of the torsion testing machine in unloaded condition
u_c	%	Combined uncertainty
u_i	%	Uncertainty component
u_rep	%	Uncertainty component due to hysteresis
u_res	%	Uncertainty component due to resolution
u_std	%	Uncertainty component due to the calibration standard used
U	%	Expanded uncertainty from increasing torques
U'	%	Expanded uncertainty from decreasing torques
v	%	Relative hysteresis of the torque measuring device of the torsion testing machine

Definitions

Torque measuring device	All components of the torque measuring device (from the torque transducer to the display unit) used to calibrate the torsion testing machine
Torque transducer	Applied torque measuring element
Calibration	Operation establishing the relationship between the torque values indicated by the torsion testing machine (with their corresponding measurement uncertainties) and those measured by one or more calibration standards
Verification	Confirmation, based on analysis of measurements in accordance with this Guideline, that the performance properties of the torsion testing machine achieve the limits given for a specified class

3 General inspection of the torsion testing machine

The calibration of the torsion testing machine may only be carried out when being in perfect operating condition. Hence a general inspection of the torsion testing machine must be carried out before calibrating the torque measuring device. The following conditions must be met:

- perfect operating condition free from defects as, for example, heavy wear;
- no disturbing or damaging environmental influences (vibrations, electrical interference, corrosion, etc.);
- the torsion testing machine must allow a smooth, jerk-free variation of the torsional moment and facilitate the application (approach) of certain torque steps with sufficient accuracy.

Note: Good metrological practice requires that prior to any maintenance activity or adjustment of the torsion testing machine, a calibration cycle be performed in order to determine and document the actual condition of the torsion testing machine.

4 Calibration of the torque measuring device of the torsion testing machine

4.1 General information

This calibration is to be carried out with each indicating device used for all torque indicating ranges. Depending on the application, the direction of rotation (clockwise and/or anticlockwise) must also be taken into account. Each additional device (e.g. trailing pointer, recording device) which may influence the measuring device must - if used - be checked according to 4.4.6.

If the torsion testing machine disposes of several measuring devices, then each measuring device has to be considered as a single testing machine.

Calibration has to be carried out by means of torque measuring devices or by using lever arm and force measuring devices, or with lever arm and masses. If the calibration of a measuring range requires more than one torque measuring instrument, then there must be an overlap step between the torque measuring instrument for the larger measuring range and the torque measuring instrument for the smaller measuring range.

The calibration may be carried out either with constantly indicated torque steps M_i or with constant reference torque steps M. Calibration may either be performed with a slowly increasing torque at increasing torque steps or with a slowly decreasing torque at decreasing torque steps.

Note: The word "constant" means that the same nominal value of M_i (or M) is applied to the three series of measurements that are carried out (see 4.4.5).

The measuring instruments used for calibration must be linked to the International System of Units.

The torque measuring devices used must meet the requirements according to DIN 51309 [3], and the force measuring devices must be in accordance with DIN EN ISO 376 [7]. The class of the instruments must correspond at least to the class indicated in Table 1 for which the torsion testing machine is calibrated.

Class of the torsion testing machine	Class of the torque measuring device	Class of the force measuring device
0.5	0.2	0.5
1	0.5	1
2	1	2
3	2	2

Table 1: Minimum requirement for a torque measuring device or force measuring device used for calibration

4.2 Determination of the resolution

4.2.1 Analogue indicating devices

The graduation lines of the scale of the indicating device must be of equal width, the width of the pointer must approximately correspond to the width of the graduation line.

The resolution r and r_z of the indicating device is given by the ratio of the pointer width to the centre distance between two adjacent graduation lines (scale division) multiplied by the value of the torque, which corresponds to one scale division. The recommended ratio is 1:2, 1:5 or 1:10; if this ratio is to be 1:10, the spacing of the graduation lines must be 2,5 mm or greater.

4.2.2 Digital indicating devices

The resolution corresponds to the scale division (digital step) of the numerical scale.

4.2.3 Variation of reading

If the display varies by more than the previously determined value of the resolution (unloaded torque measuring device, motor or drive mechanism switched on and taking into account any electrical noise), then the resolution r and r_z is assumed to be half the span of the variation, added by one scale interval (digital step).

In case of torsion testing machines with automatic measuring range changeover, the resolution changes when changing the measuring range or when changing the amplification factor of the measuring system.

Note 1: The so calculated resolution does only contain the part of the disturbing signal, but not the influence of the control technique.

4.2.4 Unit

The resolutions r and r_z must be indicated in units of torque.

4.3 Prior determination of the relative resolution of the torque measuring device

The relative resolution a of the torque measuring device results from the relationship as shown in equation (1):

$$a = \frac{r}{M_\mathrm{i}} \cdot 100 \quad \text{or} \qquad (1)$$

$$a_z = \frac{r_z}{M_\mathrm{i}} \cdot 100$$

Here,

r and r_z are the resolutions according to 4.2;

M_i is the torque indicated by the torque indicator of the torsion testing machine at the considered calibration point.

The relative resolution must be determined for each calibration point and each changeover point when changing the measuring range; it must not exceed the values specified in Table 2 or the required class of machine.

4.4 Calibration procedure

4.4.1 Installation of the torque transducer

The mounting of torque transducers in the machine must be carried out in such a way that any effects of bending and axial/transverse forces are minimized, see DIN 51309 [3]. It must be ensured that the calibration torque is introduced on the adaptation surface which has been defined as measuring side by the manufacturer, insofar as this surface is of importance for the measurement.

The direction of rotation of the calibration must be clearly defined in the calibration certificate.

4.4.2 Temperature equalisation

The calibration must be performed at an ambient temperature between 10 °C and 35 °C. The temperature at which the calibration was carried out must be stated in the calibration certificate.

An adequate waiting time is required to ensure that the torque transducer has reached a constant temperature before starting the measurement. The temperature of the torque transducer must not change by more than 2 °C from the beginning to the end of each calibration cycle. If necessary, a temperature correction must be made for the indicated values.

4.4.3 Preloading of the torsion testing machine and the torque transducer

Directly before calibration, the torque transducer installed in the torsion testing machine must be loaded at least three times in the direction to be calibrated up to the final value of the measuring range to be calibrated; in each case, there must be an intermediate unloading to zero. Equally, a preload must be applied at least once up to the final value of the measuring range to be calibrated after the torque transducer has been rotated in the direction to be calibrated. The same applies when using force measuring devices.

4.4.4 Procedure

One of the following procedures - or a combination thereof - is to be used:

a) a nominal torque M_i, indicated on the torque indicator of the torsion testing machine, is applied by the torsion testing machine and the indicated or calculated reference torque M has to be recorded;

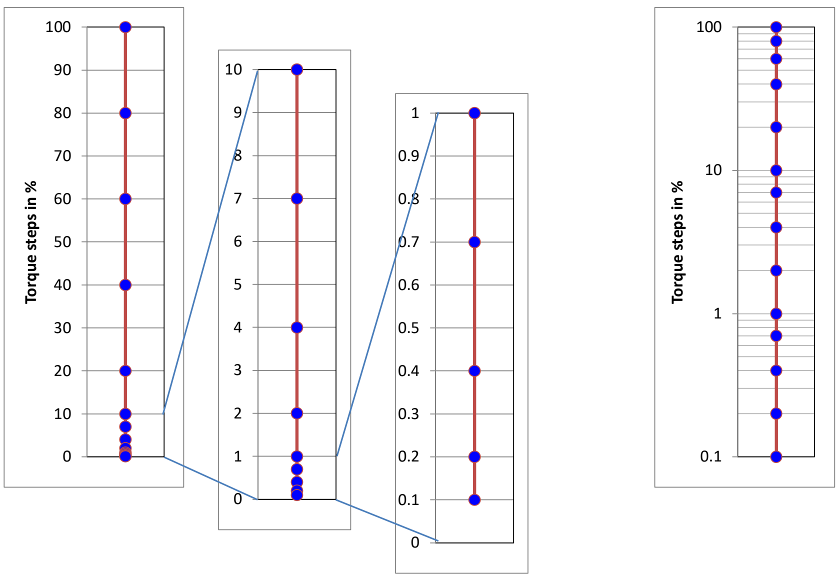
b) a nominal reference torque M, either calculated or indicated by the torque measuring instrument, is applied by the torsion testing machine; the torque M_i indicated by the torque indicating device of the torsion testing machine is to be recorded.

The expression "nominal" means that it is not necessary to repeat the exact values of the torque in each measurement series, however the values should be approximately the same.

4.4.5 Application of the torque steps

Three series of measurements must be carried out with increasing torque. For torsion testing machines that do not have more than five torque levels, the limit values given for each torque level in Table 2 may not be exceeded. For torsion testing machines having more than five torque levels, each series of measurements must include at least five torque steps distributed as equally as possible within the range 20 % to 100 % of the maximum value of the calibrated torque indicating range.

For calibrations at torque levels set below 20% of the upper limit of the torque indicating range, additional torque measurements are required. For each complete decade below 20% of the upper limit of the torque indication range, five or more different calibration torque levels are to be selected so that the ratio between two adjacent calibration torque levels is less than or equal to 2. For example, approximately 10 %, 7 %, 4 %, 2 %, 1 %, 0.7 %, 0.4 %, 0.2 %, 0.1 %, etc. of the upper limit of the torque indicating range down to the lower limit of calibration, see Figure 1. The lowest decade does not need to be a full decade and does not require five calibration points.



a) b)

Figure 1: Possible torque steps in the calibration of a torsion testing machine in a) linear and b) logarithmic representation, according to [4].

The lower limit of the torque indication range must not be smaller than r multiplied by:

– 400 for class 0.5;
– 200 for class 1;
– 100 for class 2;
– 67 for class 3.

For torsion testing machines with automatic measuring range changeover, measurements are to be carried out with at least two torque steps in each part of the measuring range in which the resolution does not change. The different torque levels (upper or lower range) can be calibrated in one calibration procedure.

Before starting the 2nd measuring series, the torque transducer must be rotated by at least 90° and preloaded again.

The relative indication error and the relative repeatability of the torque measuring device of the torsion testing machine is to be calculated for each torque level (see 4.5).

Prior to each measurement series a zero balancing must be carried out. The reading of the residual indication must take place approximately 30 seconds after the torque has been completely shut off. In case of an analogue indicating device, it is also necessary to check that the pointer freely swings back to the zero position; in case of a digital indicating device, that any value below zero is clearly visible, e.g. by a negative sign.

The relative zero deviation (zero-point drift) of each measurement series is to be calculated according to equation (2):

$$f_0 = \frac{M_{\mathrm{i0}}}{M_{\mathrm{N}}} \cdot 100 \tag{2}$$

4.4.6 Verification of accessories

Depending on how the torsion testing machine is normally operated - with or without additional equipment (trailing pointer, recording device) - it is necessary to check the proper condition and frictional resistance of the additional equipment using one of the following methods:

a) When using the torsion testing machine with additional equipment: For each torque indication range used, three series of measurements must be carried out with increasing torque (see 4.4.5), with the additional equipment being connected and switched on. An additional series of measurements without accessory equipment must be carried out for the smallest torque display range used.

b) When using the torsion testing machine without additional equipment: For each torque indication range used, three series of measurements must be carried out with increasing torque (see 4.4.5), with the additional equipment being switched off. An additional series of measurements with accessory equipment must be carried out for the smallest torque display range used.

In both cases, the relative display deviation q must be calculated from the three main measurement series, whereas the relative repeatability b must be determined from all of the four measurement series. The values obtained for b and q must be within the limits for the intended machine class as set out in Table 2. The following conditions must also be met:

$$q_{\mathrm{c}} = 100 \left| \frac{M_{\mathrm{i}} - M_{\mathrm{c}}}{M_{\mathrm{c}}} \right| \leq 1{,}5 \cdot q_{\mathrm{al}} \tag{3}$$

In the above equation (3), the value q_{al} is the maximum permissible limit value from Table 2 for the corresponding class.

4.4.7 Determination of the relative hysteresis

If required, the relative hysteresis v must be determined by calibration using the same torque steps, first with increasing and then with decreasing torque. In this case, the calibration has to be carried out by means of a torque measuring instrument calibrated according to DIN 51309 for decreasing torques, Case II or by using a force measuring instrument calibrated according to DIN EN ISO 376, Case D for decreasing forces. To determine the hysteresis, only one series of measurements with decreasing torque is required.

The measurement series for decreasing torques can be carried out directly after the measurement series 1, 2, 3 or the measurement series for checking the additional equipment.

The relative display deviation (indication error) for increasing and decreasing torque is calculated as follows from equations (4) or (5):

$$q_{\mathrm{auf}} = \frac{M_{\mathrm{i}} - M}{M} \cdot 100 \tag{4}$$

$$q_{\mathrm{ab}} = \frac{M_{\mathrm{i}}' - M'}{M'} \cdot 100 \tag{5}$$

The relative hysteresis is calculated from the difference between the values found with increasing and decreasing torque using equation (6):

$$v = q_{\mathrm{auf}} - q_{\mathrm{ab}} \tag{6}$$

For this determination, the smallest and largest torque indicating range of the torsion testing machine is to be used.

4.5 Assessment of the torque indicating device

4.5.1 Relative indication error

For each calibrated torque level, the relative indication error of the three measurement series must be individually calculated as shown in equations (7), (8), (9) and (10):

$$q_1 = \frac{(M_{\mathrm{i1}} - M_1)}{M_1} \cdot 100 \tag{7}$$

$$q_2 = \frac{(M_{\mathrm{i2}} - M_2)}{M_2} \cdot 100 \tag{8}$$

$$q_3 = \frac{(M_{\mathrm{i3}} - M_3)}{M_3} \cdot 100 \tag{9}$$

$$q = \frac{(q_1 + q_2 + q_3)}{3} \tag{10}$$

The indices 1, 2 and 3 represent the readings and calculated values of the three series of measurement for each torque step.

4.5.2 Relative repeatability

The difference between $q_{\max}$ and $q_{\min}$ constitutes the relative repeatability b for each torque step. It results from equation (11)

$$b = q_{\max} - q_{\min} \tag{11}$$

Here,

$q_{\max}$ is the algebraic maximum value of q_1, q_2 and q_3 (sometimes it might also be necessary to consider q_c);

$q_{\min}$ is the algebraic minimum value of q_1, q_2 and q_3 (sometimes it might also be necessary to consider q_c).

4.5.3 Agreement between two torque measuring devices

If two torque measuring devices are required to calibrate an (overlapping) torque step (see 4.1), the magnitude of the relative indication error between the two torque measuring devices must not be greater than the magnitude of the repeatability of the corresponding class of the torsion testing machine given in Table 2, i.e. as shown in equation (12):

$$|q_{\mathrm{T1}} - q_{\mathrm{T2}}| \leq b_{\mathrm{al}} \tag{12}$$

In this case

q_{T1} stands for the relative indication error with torque measuring device 1;

q_{T2} stands for the relative indication error with torque measuring device 2;

b_{al} represents the permissible repeatability according to Table 2.

Alternatively, it is possible to determine the accumulated uncertainty of each force-measuring device used and to compare it with the indication errors given by each device, as shown in equation (14):

$$|q_{\mathrm{T1}} - q_{\mathrm{T2}}| \leq \sqrt{U_{\mathrm{T1}}^2 + U_{\mathrm{T2}}^2} \tag{13}$$

Here, U_{T1} and U_{T2} represent the relative expanded uncertainty of the measurements - expressed as a percentage - for the same nominal torque with torque measuring device 1 and torque measuring device 2.

5 Measurement uncertainty

5.1 Introduction

There are two ways to calculate the measurement uncertainty of the torque measuring device during calibration - either from the specified limit values or from the indications provided by the measuring device. The following sections offer a detailed description of a possible calculation for the calibration by means of a torque transducer.

If the display deviation q meets the specifications given in Table 2, it is usually not corrected as a systematic error during calibration. Accordingly, the range in which the estimated relative deviation E can reasonably be expected should be $E = q \pm U$, with q being the relative indication error defined in 4.5.1 and U the expanded uncertainty [6].

5.2 Increasing torques

5.2.1 Estimate of the relative indication error

The best estimate of the relative mean error of the torque indicated by the torsion testing machine is q, that is to say the relative indication error. This estimate of the relative mean error includes an expanded measurement uncertainty U, given by equation (14):

$$U = k \cdot u_c = k \cdot \sqrt{\sum_{i=1}^{n} u_i^2} \tag{14}$$

with

k	being the coverage factor;
u_c	being the combined uncertainty;
u_1 to u_n	being the respective standard uncertainties.

u_1 to u_n contain contributions relating to repeatability, resolution and transfer standard. Other uncertainty contributions that must be taken into account may be related to the influences of torque introduction and operating personnel.

5.2.2 Repeatability

The contribution of the standard uncertainty u_{rep} related to the repeatability is the standard deviation of the estimate of the mean relative indication error, and is calculated as in equation (15):

$$u_{rep} = \sqrt{\frac{1}{n(n-1)} \sum_{i=1}^{n} (q_i - q)^2} \tag{15}$$

Here,

n	is the number of readings for each indicated test level;
q_i	is the indication error at indicated test level (%);
q	is the mean value of the indication error at indicated test level (%).

5.2.3 Resolution

The uncertainty due to the resolution of the torsion testing machine for each torque is the square root of the sum of the squares of the following two components:

– uncertainty component due to the resolution of the indication of the torsion testing machine with acting torque, given by the relative resolution a divided by twice the square root of three and

– uncertainty component due to the resolution of the indication of the torsion testing machine in unloaded condition, given by the relative resolution a_z (calculated according to 4.3 and with calibration torque M_i as in equation (1)) divided by twice the square root of three.

The uncertainty due to the resolution is shown in equation (16):

$$u_{\text{res}} = \sqrt{\left(\frac{a}{2\sqrt{3}}\right)^2 + \left(\frac{a_z}{2\sqrt{3}}\right)^2} \tag{16}$$

5.2.4 Transfer standard

The standard uncertainty in relation to the transfer standard u_{std} is given by equation (17):

$$u_{\text{std}} = \sqrt{u_{\text{cal}}^2 + A^2 + B^2 + C^2} \tag{17}$$

Here,

u_{cal}	is the relative calibration uncertainty of the transfer standard;
A, B and C	are possible uncertainty contributions due to temperature, drift and linear approximation to the regression function.

5.2.5 Expanded uncertainty

Once all relevant standard uncertainties have been considered (including the other contributions mentioned above), the combined uncertainty u_c has to be multiplied by a coverage factor k to determine the expanded uncertainty U. Although k can also be calculated from the number of effective degrees of freedom, it is recommended to use a value of $k = 2$. The principles set out in [6] should be taken into account.

The estimated relative mean deviation E can be expected to be within the range shown in equation (18):

$$E = q \pm U \tag{18}$$

and - as shown in equation (19) - the generated mean torque M can be given as:

$$M \approx M_{\text{i}} - \frac{M_{\text{i}}}{100}(q \pm U) \tag{19}$$

5.3 Decreasing torques

In case of decreasing torques, the combined uncertainty u_c' is to be calculated from the uncertainty contributions of q and v. It is assumed that the uncertainty contribution of the relative hysteresis v is equal to that of the relative indication error q with increasing torque. The combined uncertainty u_c' is therefore estimated as shown in equation(20):

$$u_c' = \sqrt{2} \cdot u_c \tag{20}$$

To calculate the expanded uncertainty U', the combined uncertainty u_c' has to be multiplied by the coverage factor k. The estimated relative deviation E' can roughly be expected to be within the range shown in equation (21):

$$E' = (q + v) \pm U' \tag{21}$$

with

q	being the relative indication error with increasing torque;
v	being the relative hysteresis.

As shown in equation (22), the generated mean decreasing torque can be given as:

$$M' \approx M_i' - \frac{M_i'}{100}\left[(q + v) \pm U'\right] \tag{22}$$

6 Classes of torque indicating ranges of the torsion testing machine

Table 2 shows the maximum permissible limits for the various relative deviations of the torque measuring device and the relative resolution of the torque indicating device which are relevant for classifying the torque indicating ranges of the torsion testing machine.

However, the classification of all torque indicating ranges of a torsion testing machine may be restricted, where applicable, by the "verification of accessories" and by the "relative hysteresis".

The classification of a torque indicating range may only be considered as conforming to standards with a verification covering at least 20 % to 100 % of the maximum value of the calibrated torque indicating range. If for technical reasons the final value cannot be achieved, it will suffice to achieve at least 80 % of the maximum value. In this case, a corresponding note in the calibration certificate is required. In any case, the minimum number of torque steps must be taken into account.

Class of the torque indicating ranges of the torsion testing machine	**Maximum permissible limit value** %					
	Relative					
	Display deviation q	**repeatability** b	**hysteresis** [1)] v	**Zero error** f_0	**Relative resolution** a	**Relative expanded uncertainty** U
0.5	± 0.5	0.5	± 0.75	± 0.05	0.25	0.4
1	± 1.0	1.0	± 1.5	± 0.1	0.5	0.7
2	± 2.0	2.0	± 3.0	± 0.2	1.0	1.3
3	± 3.0	3.0	± 4.5	± 0.3	1.5	2.0

1) According to 4.4.7, the relative hysteresis is determined only on request.

Table 2: Characteristic quantities of the torque measuring device

Adherence to this Guideline ensures that the uncertainty is explicitly taken into account as required by some accreditation standards. A reduction of the permissible display deviation by the amount (magnitude) of the uncertainty would result in a double counting of the uncertainty. Classification of a torsion testing machine calibrated and certified to meet the requirements of a specific class does not ensure that the accuracy including uncertainty will be smaller than a predefined value. For example, the indication error including uncertainty of a Class 1 torsion testing machine will not necessarily be less than 1.0 %.

Note 1: Investigations into the calibration of materials testing machines according to DIN EN ISO 7500-1 have shown (see [4], [5]) that a large number of testing machines no longer reach the existing class limits when adding the measurement uncertainty to the indication error. Hence, the DIN Standards Committee NA 062-08-11 AA for the calibration of materials testing machines according to DIN EN ISO 7500-1 has provided corresponding guidance on the consideration of measurement uncertainty in the classification of materials testing machines [2]. By taking into account the measurement uncertainty according to Table 2, the limit values of the display deviation (indication error) will not be reduced.

Note 2: With regard to the comparatively high limit values of the relative expanded measurement uncertainty given in Table 2, it should be noted that the repeatability and display resolution of the torsion testing machine to be calibrated may also play a significant role in the calculation of the measurement uncertainty U. The measurement uncertainty of the torque measuring devices used for calibration is significantly lower.

7 Documentation of measurement results

7.1 General information

The calibration certificate must contain at least the following information:

a) a reference to this guideline, i.e. DKD-R 9-1;

b) identification of the torsion testing machine (manufacturer, type, year of manufacture if known, serial number) and, if available, identification of the torque measuring device (manufacturer, type, serial number);

c) place of installation of the torsion testing machine;

d) identification of the standard used for calibration;

e) calibration temperature;

f) verification date;

g) name or mark of the calibration laboratory.

7.2 Verification results

The results must include the following information:

a) special characteristics observed during the general inspection of the torsion testing machine;

b) type of torque application during calibration (clockwise, anti-clockwise, clockwise/anti-clockwise) for each torque measuring device used, assignment to a class for each calibrated torque indicating range and, if required, the individual values for the relative errors of the indication deviation, repeatability, hysteresis, zero drift and resolution;

c) lower limit of the respective torque indicating range to which the evaluation applies.

8 Intervals between verifications

The time between two verifications depends on the type of torsion testing machine, its condition and the frequency of use. Unless otherwise specified, it is recommended that the intervals between the verifications do not exceed 12 months.

Verification of the torsion testing machine is mandatory when moved to a new location and if it has been disassembled for this purpose, or if it has undergone major repairs or adjustments.

9 Bibliography

[1] DIN EN ISO 7500-1:2018-06: Metallische Werkstoffe – Kalibrierung und Überprüfung von statischen einachsigen Prüfmaschinen – Teil 1: Zug- und Druckprüfmaschinen – Kalibrierung und Überprüfung der Kraftmesseinrichtung.

[2] DIN EN ISO 7500-1 Bbl 4: Prüfung von statischen einachsigen Prüfmaschinen – Teil 1: Zug- und Druckprüfmaschinen – Prüfung und Kalibrierung der Kraftmesseinrichtung; Beiblatt 4: Informationen zur Berücksichtigung der Messunsicherheit bei der Klassifizierung von Werkstoffprüfmaschinen.

[3] DIN 51309: Werkstoffprüfmaschinen Kalibrierung von Drehmomentmessgeräten für statische Drehmomente.

[4] Gerber, S.; Ellermeier, J.: Neue DIN EN ISO 7500-1 für die Kalibrierung von Werkstoffprüfmaschinen. Vortrag auf dem Werkstofftechnischen Kolloquium Mess- und Kalibriertechnik, MPA Darmstadt, 29.09.2016.

[5] Gerber, S.; Ellermeier, J.: Qualitätssicherung durch Kalibrierung in der Werkstoffprüfung. In: Frenz, H. und Langer, J. (Hrsg.): Fortschritte in der Werkstoffprüfung für Forschung und Praxis. Werkstoffprüfung 2017, 30.11./01.12.2017, Berlin, Tagungsband, S. 11-16.

[6] ISO/IEC Guide 98-3, Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement (GUM:1995).

[7] DIN EN ISO 376: Metallische Werkstoffe – Kalibrierung der Kraftmessgeräte für die Prüfung von Prüfmaschinen mit einachsiger Beanspruchung.

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