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Torque measuring devices – Calibration and classification using continual torque application – Method

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Foreword

Publishing information

This British Standard is published by BSI Standards Limited, under licence from The British Standards Institution, and came into effect on 31 December 2018. It was prepared by Panel ISE/101/1/2, *Torque measuring and testing*, under the authority of Subcommittee ISE/101/1, *Uniaxial testing*, and Technical Committee ISE/101, *Test methods for metals*. A list of organizations represented on these committees can be obtained on request to their secretary.

Supersession

BS 7996:2018 supersedes BS 7996:2009, which is withdrawn.

Information about this document

This British Standard describes a method of calibration and classification only and should not be used or quoted as a specification.

This revision introduces the relative measurement uncertainty interval, the range in which the expected error is likely to lie, calculated as the sum of the absolute relative deviation and the expanded uncertainty.

Use of this document

It has been assumed in the drafting of this British Standard that the execution of its provisions is entrusted to appropriately qualified and competent people.

Presentational conventions

The provisions of this standard are presented in roman (i.e. upright) type. Its requirements are expressed in sentences in which the principal auxiliary verb is “shall”.

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

1 Scope

This British Standard specifies a method for the calibration and classification of torque measuring devices using continuous torque application where the inertial effects are minimal. This includes torque measuring devices used for the calibration of torque tools.

The information to be given on the certificate of calibration is also specified in this standard.

[Annex A](#) provides diagrams of the continuous application of torque, and examples for the calibration of torque measuring devices. [Annex B](#) gives an example of determining uncertainty of the calibration results of the torque measuring device. [Annex C](#) shows how to calculate mechanical and electronic bandwidth.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

JCGM 200, *International vocabulary of metrology — Basic and general concepts and associated terms (VIM)*¹

3 Terms, definitions, abbreviations and symbols

For the purposes of this British Standard, the terms and definitions given in JCGM 200 and the following apply.

3.1 acceleration period

time interval during which the rate of change of applied torque starts from zero and then attains a constant value

3.2 bandwidth of the reference standard, B_{RS}

response of the reference standard to a step input (expressed in hertz)

NOTE See [Annex C](#).

3.3 bandwidth of the torque measuring device, B_{TMD}

response of the torque measuring device to a step input (expressed in hertz)

NOTE See [Annex C](#).

3.4 calibration torque, T

torque, with traceability derived from national standards of mass, length and time, and of specified expanded uncertainty of measurement (U_T), which can be applied to the torque measuring device

3.5 constant rate period

time interval between the acceleration and deceleration periods during which the rate of change of applied torque is constant

¹ Third edition available at: https://www.bipm.org/utls/common/documents/jcgm/JCGM_200_2012.pdf [Last viewed: 8 November 2018].

3.6 continuous application of torque

sequence consisting of three time periods: acceleration period, constant rate period and deceleration period

NOTE Refer to [Figure A.1](#) for an illustration of this

3.7 data acquisition system

electronic module that has the ability to acquire signals from a torque measuring device and transmit data based on those signals for analysis

NOTE Where analogue signals are acquired by the torque measuring device, and these are converted into a digital data stream using an analogue to digital converter, the stream of data may be digitally filtered, re-sampled and stored, or logged ready for analysis.

3.8 data skew

change in applied torque during the period between nominally synchronized readings from the reference standard and the torque measuring device

NOTE This period can be due to the readings being taken at different times or propagation delays. It can be determined at various stable torque values throughout the torque calibration range, by applying a sharp mechanical stimulus to the system and measuring the difference in response times of the outputs from the reference standard and the torque measuring device.

3.9 deceleration period

time interval during which the rate of change of applied torque decreases from a constant value to zero

3.10 deflection, d

algebraic difference between the indicator reading prior to the application of a torque and the indicator reading for each applied torque in a given measurement series

NOTE The deflection may be derived from either digital data output or visual data output.

3.11 loading direction

direction of applied torque, either clockwise or anti-clockwise about the axis of rotation, when viewed from the end of the torque measuring device to which the calibration torque is applied

3.12 lower limit of calibration, $T_{\min}$

lower value of torque at which a torque measuring device of a given class can be calibrated

3.13 maximum calibration torque, $T_{\max}$

upper calibration torque value applied to the torque measuring device

3.14 rate of applied torque, R_T

change of torque with time

3.15 recording rate, R_r

rate at which the visual or digital output is recorded for subsequent analysis

NOTE 1 The data may be manually recorded or recorded by an optical recognition system, i.e. video, for subsequent analysis.

NOTE 2 The recording rate is sometimes known as the refresh rate.

3.16 reference standard, RS

equipment used to generate or to measure the reference torque applied to the torque measuring device that is being calibrated

NOTE Torques may be generated by a power source monitored by the reference standard.

3.17 relative error of indication <incremental torques>, E_i

for a given applied torque, the difference between the mean incremental deflection and the applied torque

NOTE 1 For the purposes of this standard, relative error of indication is expressed as a percentage of applied torque.

NOTE 2 Relative error of indication is only used where the deflection is in units of torque.

3.18 relative error of indication <incremental and decremental torques>, E_{id}

for a given applied torque, the difference between the deflection with the maximum deviation from the applied torque and the applied torque

NOTE 1 For the purposes of this standard, relative error of indication is expressed as a percentage of applied torque.

NOTE 2 Relative error of indication is only used where the deflection is in units of torque.

3.19 relative error of interpolation <incremental torques>, E_{it}

for a given applied torque, the difference between the value of the mean incremental deflection and the corresponding calculated value of deflection, obtained from a mathematically fitted curve

NOTE For the purposes of this standard, relative error of interpolation is expressed as a percentage of the computed deflection for the given increasing torque.

3.20 relative error of interpolation <incremental and decremental torques>, E_{itd}

for a given applied torque, the difference between the deflection with the maximum deviation from the corresponding calculated deflection obtained from a curve fitted to the incremental deflections and this corresponding calculated deflection

NOTE For the purposes of this standard, relative error of interpolation is expressed as a percentage of the computed deflection for the given increasing torque.

3.21 relative repeatability, R_1

closeness of the agreement between the results of two successive measurements from the same applied torque, carried out under the same conditions of measurement

3.22 relative reproducibility, R_2

closeness of agreement between the results of successive measurements from the same applied torque, carried out under changed conditions of measurement

3.23 relative residual deflection, R_0

maximum residual deflection obtained from all the series of torques

NOTE For the purposes of this standard, relative residual deflection is expressed as a percentage of the mean deflection for the maximum torque applied.

3.24 relative reversibility, R_3

difference between the deflection obtained from the last given torque series applied in an increasing mode and the deflection obtained from the same given torque applied in a decreasing mode

NOTE For the purposes of this standard, relative reversibility is expressed as a percentage of the deflection of the last series for the given torque, applied in an increasing mode.

3.25 relative measurement uncertainty interval, U'_{interval}

range in which the expected error is likely to lie, calculated as the sum of the absolute relative deviation and the expanded uncertainty

3.26 residual deflection, d_0

algebraic difference between the indicator readings before and after the application of a single series of torques

3.27 resolution, r

smallest discernible measurement interval on the torque measuring device indicator

3.28 sampling rate

rate at which the data acquisition system samples the signal

NOTE An analogue waveform may be sampled at a much higher rate than the rate at which data are available.

3.29 torque

product of tangential force and length applied about a known centre of rotation

3.30 torque measuring device, TMD

system comprising electrical, electronic, mechanical, hydraulic or optical torque transducer, with associated instrumentation, including the automated logging of data when part of the device

4 Preparation for calibration**4.1 Reference standard****4.1.1 Uncertainty of calibration torques**

Values for the maximum permissible uncertainty of the calibration torques applied for the determination of different classifications of the torque measuring device shall not exceed the values given in [Table 1](#). Where a reference standard is used to determine a calibration torque, it shall conform to [Table 1](#).

The uncertainty of the calibration torque shall take into account factors such as bandwidth of the system and its own calibration traceability.

Table 1 — *Uncertainty of calibration torques*

Class of torque measuring device to be calibrated	Maximum permissible uncertainty of calibration torque applied ^{A)}
	%
0.05	0.01
0.1	0.02
0.2	0.04
0.5	0.10
1.0	0.20
2.0	0.40
5.0	1.00

^{A)} Using a coverage factor of $k = 2$ to give a confidence level of approximately 95%.

4.1.2 Traceability of measurements

All definitive measurements, such as mass, length, time and temperature, shall be traceable to national standards, as evidenced by a certificate of calibration.

4.1.3 Bandwidth, B_{RS}

The bandwidth of the reference standard shall be determined.

Two bandwidth contributions shall be taken into consideration:

- a) mechanical: this is controlled by the natural frequency of the sensing element, i.e. transducer (see [C.2](#));
- b) electronic: this is a function of the instrumentation used (see [C.3](#)).

The bandwidth of the reference standard shall be taken as the lower of these two values.

4.2 Condition and identification of a torque measuring device

4.2.1 Calibration shall not be commenced unless the torque measuring device is considered to be in good working order. The maximum working torque shall first have been established.

NOTE Good working order includes the drive components being of a sufficiently good fit to exert a minimum bias on the system.

4.2.2 All parts of the torque measuring device shall be uniquely identified, including the following, where applicable:

- a) signal cables;
- b) switch boxes;
- c) interfaces;
- d) data acquisition systems;
- e) computers;
- f) software (where information is available); and
- g) mechanical drive adapters.

4.2.3 Where an electrical indicator used with a torque measuring device is replaced with another, the following requirements shall be met to ensure that the calibration is not invalidated.

- a) The original and replacement indicators shall have calibration certificates, traceable to national standards, which give the results of calibration in terms of electrical units (volt, ampere). The

replacement indicator shall be calibrated over a range equal to or greater than the range for which it is used with the torque transducer, and the resolution of the replacement indicator shall be at least equal to the resolution of the original indicator when it is used with the torque transducer.

NOTE If the indicator is set to display in units of torque, the same conversion factors should be used in the replacement indicator.

- b) The units and excitation source of the replacement indicator shall be respectively of the same quantity (e.g. 5 V, 10 V) and type (e.g. DC or AC frequency).
- c) The uncertainty of each indicator (both the original and the replacement indicators) shall not significantly influence the uncertainty of the whole torque measuring device. It is recommended that the uncertainty of the replacement indicator be no greater than $\frac{1}{3}$ of the uncertainty of the entire system.
- d) If it is necessary to replace cables, the replacement cables shall be of the same specification as the originals.

4.2.4 The bandwidth of the torque measuring device, B_{TMD} , shall be determined as the lower of the following two contributions:

- a) mechanical: this is controlled by the natural frequency of the sensing element, i.e. transducer (see [C.2](#));
- b) electronic: this is a function of the instrumentation used (see [C.3](#)).

4.3 Resolution of the indicator

COMMENTARY ON [4.3](#)

An indicator can be a direct reading display or the output of a data acquisition system.

4.3.1 Analogue scale

When the output of the torque measuring device is measured by an indicator with an analogue scale, e.g. a dial gauge or Bourdon tube instrument, the resolution, r , shall be determined from the ratios between the width of the pointer and the centre-to-centre distance between two adjacent scale graduation marks (scale interval) multiplied by the value of torque which one scale interval represents.

NOTE 1 The ratios should be $\frac{1}{2}$, $\frac{1}{5}$ or $\frac{1}{10}$.

A spacing of at least 1.25 mm shall be used for the estimation of a tenth of the division on the scale.

NOTE 2 A vernier scale of dimensions appropriate to the analogue scale can be used to allow direct fractional reading of the instrument scale division.

4.3.2 Digital scale

When the output of the torque measuring device is measured by an indicator with a digital scale, the resolution, r , shall be considered to be one increment of the last active number on the numerical indicator.

4.3.3 Optical recognition system

When using an optical recognition system, i.e. video, the video frame rate shall be at least 5 times the display update being recorded.

4.3.4 Variation of readings

If the readings fluctuate by more than the value previously calculated for the resolution, r (with no torque applied to the torque measuring device), the resolution shall be deemed to be equal to half the range of fluctuation.

4.3.5 Units

The resolution, r , shall be converted to units of torque.

4.3.6 Modification of resolution to permit increased rate of applied torque

Where an increased rate of applied torque is required (see 4.5), the previously calculated resolution, r , shall be increased to a value that meets the criteria in formulae 1 and 2, e.g. from 0.1 N·m to 1 N·m.

NOTE This will impact the lower limit of calibration (see 4.4).

4.4 Lower limit of calibration, $T_{\min}$

To ensure that the classification is consistent with the resolution of the torque indicator, a lower limit of calibration shall be determined. The calibration shall not be performed below this lower limit, given by the formula:

$$T_{\min} = a \cdot r$$

where:

r is the resolution determined in accordance with 4.3; and

a has the following values:

- 4 000 for a class 0.05 torque measuring device;
- 2 000 for a class 0.1 torque measuring device;
- 1 000 for a class 0.2 torque measuring device;
- 400 for a class 0.5 torque measuring device;
- 200 for a class 1.0 torque measuring device;
- 100 for a class 2.0 torque measuring device; and
- 40 for a class 5.0 torque measuring device.

4.5 Rate of applied torque

The rate of applied torque shall be limited, using formulae (1) and (2), to a maximum value at which the change in applied torque from one reading to the next, for both the torque measuring device and the reference standard, does not exceed one count of resolution.

$$R_T \leq R_{r(\text{TMD})} \cdot r \quad (1)$$

$$R_T \leq R_{r(\text{RS})} \cdot r \quad (2)$$

The rate of applied torque shall also be limited, using formulae (3) and (4), to a maximum value at which the bandwidths of both the torque measuring device and the reference standard do not significantly affect the calibration results.

$$R_T \leq \frac{B_{TMD} \cdot T_{\max}}{10} \quad (3)$$

$$R_T \leq \frac{B_{RS} \cdot T_{\max}}{10} \quad (4)$$

where:

- R_T is the rate of applied torque;
- $R_{r(TMD)}$ is the recording rate of the torque measuring device;
- r is the resolution;
- $R_{r(RS)}$ is the recording rate of the reference standard;
- B_{TMD} is the bandwidth of the torque measuring device;
- B_{RS} is the bandwidth of the reference standard; and
- $T_{\max}$ is the maximum calibration torque.

NOTE For example, a 20 N·m torque measuring device with a resolution of 0.001 N·m and a bandwidth of 500 Hz is calibrated against a reference standard with a bandwidth of 1 kHz, with readings being taken at a rate of 1 kHz. Formulae (1) and (2) limit the torque application rate to a maximum value of 1 N·m·s⁻¹, while formula (3) limits it to a maximum value of 1 kN·m·s⁻¹, and formula (4) to a maximum value of 2 kN·m·s⁻¹. Taking all four formulae into account, the torque application rate is not to exceed 1 N·m·s⁻¹. Increasing the resolution to 0.01 N·m, as allowed by 4.3.6, would increase the maximum permissible rate to 10 N·m·s⁻¹ but would negatively impact the lower limit of calibration. Alternatively, the torque application rate may be increased between data samples in accordance with 6.2.5 if this does not affect the measured values.

4.6 Number of calibration orientations (see Annex A)

For classes 0.05 and 0.1, the torque measuring device shall be calibrated in either three different mounting positions, each rotated 120° about the measurement axis, or in four different mounting positions, each rotated 90° about the measurement axis. For all other classes, the torque measuring device shall be calibrated at a minimum of two different mounting positions at least 90° apart.

Where the design of the torque measuring device does not allow it to be rotated, a physical disconnection and reconnection of the reference standard followed by a third calibration series shall be deemed acceptable. For such devices, classification shall be limited to class 0.2 and above.

5 Preliminary procedure

5.1 Alignment

- 5.1.1 Place the torque measuring device in an appropriate mounting and position it so that it can, where possible, be rotated about its principal measuring axis between series.

NOTE Any bending applied to the torque measuring device during the calibration should be kept to a minimum. Where it is felt that the bending applied could have a significant effect on the torque measuring device's deflection, this should be considered as part of the uncertainty budget.

- 5.1.2 Ensure that there is minimal misalignment between the reference standard and the torque measuring device.

5.2 Temperature considerations

- 5.2.1 Where the torque measuring device is electrical, connect the torque measuring device, switchboxes, interfaces, etc., using the associated electrical cables. Switch on and allow to warm up for the period