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An approach for using uncertainty value as decision rule for conformity in torque devices

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ABSTRACT:

Torque devices are roughly calibrated in the world according to BS 7882: 2017. Class determination of these torque devices are found in the calibration results. The uncertainty budget for these measurements is not taken into account in this class determination. Recently, ISO/IEC 17025:2017 defined a requirement to classify measuring instruments according to the uncertainty values and decision rules has to be cleared. Considering classification as conformity statement determination, so decision rules has to be mentioned and identified. Harmonization between ISO 17025:2017 and BS 7882:2017, the decision rule for torque devices classification must take into account the uncertainty budget value. Since uncertainty include all the parameter and sources of errors that may affects the classification decision, so it is the more accurate and the more realistic to be used as a base for classification. Therefore, the extended uncertainty value is equivalent to all parameters that may affect the performance of torque devices. Therefore, it is logical and accurate to use it as the basis for the classification rule. The investigation involved in this paper was developed based on shared risk bases. This paper can be used for BS 7882: 2017 Next Edition to use the uncertainty values as the basis for the classification rule for torque devices.

KEYWORDS: *Uncertainty, torque devices, decision rule, BS 7882.*

1 INTRODUCTION

In various applications in manufacturing, influencing measurements are procedures required to estimate critical limits for products or items. It is necessary to estimate the clamping torque of the screws, dimensional qualifications, chemical analysis, etc. These applications can be used in material testing, industrial weighing and parts measurements [1-2]. In all measurements and applications, there will be an estimate of uncertainty for the measured parameters. For torque measurements, the devices used to make the measurements must be traceable to achieve the SI unit of torque, within the claimed uncertainty. The torque converter must be used either to calibrate the industrial torque converter or to directly measure the torque as this is fed into the calibration torque machines. These torque transducers shall be traceable to national torque standard machines having recognized calibration measurement capabilities (CMC) [3].

The calibration methods for calibrating the torque transducers will generally be performed according to a documented procedure such as BS 78822017 or DIN 51309-2013 and ASTM 2428-15a [4] the documented calibration procedure defined classification criteria for a torque transducer based on various relative errors such as relative propagation and repetition errors relative interpolation error relative zero error relative reflection error and relative creep error [5] as this classification is a compliance statement such as pass/fail in tolerance / out of tolerance in specification / out of specification it is defined as compliance or non-compliance with the relevant standard specification or requirement [6].

According to the ISO 17025:2017 standard, the laboratory must report the declaration of conformity based on pre-established decision guidelines. These decision guidelines describe how to consider measurement uncertainty when providing guidance for compliance with the specific requirements of the decision guidelines and conformance statements. ILAC G8:09:2019 defines different states in Declaration of Conformity Definition [7]. The aim of this manuscript is to align the requirements of ISO 17025:2017 regarding decision guidelines and the use of uncertainty in classification decisions. An upcoming release of BS 7882:2017 to calibrate the torque transducer and to show a proposed proposal to consider balancing uncertainty rather than differential error as the basis for BS 7882:2017 calibration ratings and instrument ratings. Torque measurement is based solely on relative errors as a criterion for torque converter ratings is a type of declaration of conformity that It is provided and the decision guidelines for this Classification [8] are defined according to the latest version of the ISO/IEC standard 17025:2017 certification, which is required to determine the decision guidelines for a declaration of conformity, these decision guidelines must take into account budget uncertainty as the basis for determining conformity law because BS 7882-2017 conveys non-compliance Presence of relative errors for classification decision and no dependence on uncertainty. There is a clear contradiction between BS 7882:2017 and the newly adopted standard ISO/IEC 17025:2017 [9-10]. According to BS 7882:2017 Relative errors should be calculated using equations 1 to 10 and compared with the values given in Table 1 will select the class with the highest error value. (worst case will be the overall class).

Table 1 Criteria for classification of torque measuring devices

Class	**Permissible values%**					
	Relative repeatability R_1	**Relative reproducibility R_2**	**Relative error of interpolatio**	**Relative residual deflection**	**Relative reversibility R_3**	**Relative error of indication**
0.05	±0.025	±0.05	±0.025	±0.01	±0.062	±0.025
0.1	±0.05	±0.10	±0.05	±0.02	±0.125	±0.05
0.2	±0.10	±0.20	±0.10	±0.04	±0.250	±0.10
0.5	±0.25	±0.50	±0.25	±0.10	±0.625	±0.25
1.0	±0.50	±1.00	±0.50	±0.20	±1.250	±0.50
2.0	±1.00	±2.00	±1.00	±0.40	±2.500	±1.00
5.0	±2.50	±5.00	±2.50	±1.00	±6.250	±2.50

To resolve this conflict, the conduct of this study was considered. The objective of this article is to provide a proposed classification standard for torque gauges. This proposal is intended to serve as a normative standard of BS7882-2017 as the basis for amending the classification standard for the next version of this standard and is in line with ISO/IEC 17025:2017 and International Requirements for Conformity Declarations which provide such as ILAC G8:09/2019 Guidelines for Decision Rules and Statement of Conformity.

To consider the risks in the Declaration of Conformity, there are three main risks involved in approaching uncertainty by making conformance decisions or compliance with calibration results required to meet specifications, standards and regulatory limits. The matching decision rules can then be applied accordingly.

In short, they are the risks of false acceptance of a test result, the risk of false rejection of a test result and the combined risks. The basic basis of the decision rule is to define the "acceptance region" and "rejection region," so that if the measurement result falls within the acceptance region, the element is declared in agreement, and if it is in the rejection region, it is declared incompatible [11]. Hence, the decision rule documents the method for determining acceptance and rejection regions, ideally including the minimum acceptable probability that the value of the target values will be between the specified limits. The simple decision rule widely used today is in the case where the measurement indicates non-compliance with the upper or lower bound of the specification if the measured value exceeds the bound due to the extended uncertainty, U(exp.) [12].

2 Mathematical backgrounds for BS7882-2017 classification

According to BS7882:2017 the apparatus for measuring torque have to be classified from 20% to 100% of the maximum nominal capacity of the torque gauge apparatus. These classifications are based on the highest value of the relative errors of Indication identified below. The estimation of those is calculated using equations blew. The class decision will be based on the highest value in the calculated relative errors of Indication. These errors will be identified as follow;

2.1 Relative error of repeatability (R_1)

The errors of repeatability are determined for each measured value of increasing torque applied in a clockwise or counter clockwise direction, for the first and second series of applied torque using the following equations [BS 7882:2017].

$$\boldsymbol{R_1} = \frac{(d_1 - d_2)}{d_{R1}} \times \mathbf{100} \qquad (1)$$

where:

R_1 is the relative repeatability error.

d_1 and d_2 are the deflections for a given increasing torque in S_1 and S_2 in Figure 1.

d_{R1} is the mean deflection for a given torque.

Where:

$$d_{R1} = \frac{d_1 + d_2}{2} \qquad (2)$$

2.2 Relative error of reproducibility (*R2*)

The errors of reproducibility are determined for each value of increasing torque applied in a clockwise or counter clockwise direction for the series of applied torque, which depending on the orientations of the applied torque [BS 7882:2017].

$$R_2 = \frac{(d_{max.} - d_{min.})}{d_{R2}} \times 100 \qquad (3)$$

where:

R_2 is the relative reproducibility error.

$d_{max.}$ and $d_{min.}$ are the maximum and minimum deflection for a given increasing torque from all series.

d_{R2} is the mean deflection for a given torque is the mean deflection calculated from the first series at each orientation in Figure 1.

Where:

$$d_{R2} = \frac{d_1 + d_3 + d_4}{3} \qquad (4)$$

2.3 Relative error of interpolation (E_{it})

The errors of interpolation are determined using a first-, second- or third-degree equation giving the deflection d_{R2} as a function of the calibration torque. The equation used shall be indicated in the calibration report. The relative interpolation error shall be calculated from the equation:

$$E_{it} = \left[\frac{(d_{R2} - d_{Comp})}{d_{Comp}}\right] \times 100 \qquad (5)$$

Where:

E_{it} is the relative error of interpolation;

d_{comp} is the computed deflection for the given increasing torque.

2.4 Relative error of residual deflection (R_o)

Determine the maximum residual deflection obtained from the applied series of torques and express this as a percentage of the mean deflection at maximum applied torque using equation (6).

$$R_0 = \frac{d_{0max.}}{d_{R2Max.}} \times 100 \qquad (6)$$

where:

R_0 is the relative residual deflection;

d_{0max} is the maximum residual deflection;

d_{R2max} is the mean deflection at maximum applied torque.

2.5 Relative error of reversibility (R_3)

The error of reversibility is determined as a percentage of the deflection for the given torque from the last applied series of torques (S_5 and S_6) in Figure 1.

$$R_3 = \frac{(d_{dec} - d_{inc})}{d_{inc}} \times 100 \quad (7)$$

where:

R_3 is the relative reversibility error.

d_{inc} is the deflection for the application of the last series of a given increasing torque;

d_{dec} is the deflection for the application of the corresponding decreasing torque

2.5 Relative error of indication (E_i)

The errors of indication are determined for each value of increasing applied torque in a clockwise or counter clockwise direction for the given torque. Where, the mean deflection (d_{R2}) is calculated from the applications of the given torque and express the relative error of indication as a percentage of the true value of torque (T_a),

$$E_i = \frac{(d_{R2} - T_a)}{T_a} \times 100 \quad (8)$$

where:

E_i is the relative error of indication;

d_{R2} is the mean deflection calculated from the first series at each orientation;

T_a is a given increasing calibration torque

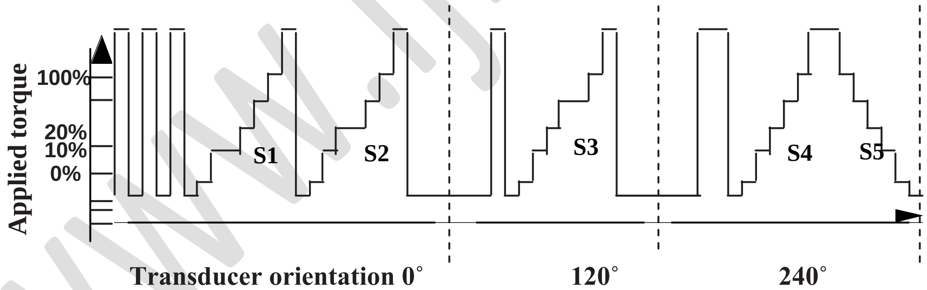

Fig. 1 preloading and calibration sequences for a torque measuring device with six increasing and decreasing torques, BS 7882:2017

3. EXPERIMENTAL SET UP AND CALIBRATION PROCEDURE.

A torque transducer with capacity 1000 Nm manufactured by HB was used. It was calibrated on NIS 1000 Nm secondary standard torque machine. This machine is internationally recognized by BIPM with uncertainty of $\pm 0.025\%$. the calibration results of the 1000 Nm torque transducer are monitored by DMP40 digital precision measuring amplifier (HBM). The calibration is directed with applying two series of increasing torque values only without rotating the torque transducer. Then applying one series of increasing torque values with rotating the torque device at 120° and one series of increasing and decreasing torque values with rotating torque device at 240° as shown in fig.1.

4. ANALYSIS OF THE UNCERTAINTY BUDGET

The combined uncertainty is calculated according to the equations below:

$$u_c = \sqrt{\sum_{i=1}^{n} u_i^2} \qquad (9)$$

Where:

u_c is defined as the combined uncertainty

u_i are the uncertainty associated with the following components.

u_1 is the standard uncertainty of the calibration torque.

u_2 is the standard uncertainty of the relative reproducibility.

u_3 is the standard uncertainty of the relative repeatability.

u_4 is the standard uncertainty of the relative resolution of indicator.

u_5 is the standard uncertainty of the relative creep of the device.

u_6 is the standard uncertainty of the temperature of the device

u_7 is the standard uncertainty of the relative interpolation error.

u_8 is the standard uncertainty of the reversibility of the device

4.1 Evaluating the relative standard uncertainty of calibration torque, u_1

u_1 This uncertainty value is the reference standard uncertainty value of applied torque by the calibration of secondary standards torque machine on the torque devices. This value can be obtained from the technical specification of the machine or torque calibration machine certificates.

4.2 Evaluating the relative standard uncertainty of reproducibility, u_2

the standard uncertainty related to reproducibility of the measured torque is calculated in relative value by the following equations:

$$u_2 = \frac{0.5R_2}{100\times\sqrt{2}} \qquad (10)$$

4.3 Evaluating the relative standard uncertainty of repeatability, u_3

the standard uncertainty related to repeatability of the measured torque is calculated in relative value by the following equations:

$$u_3 = \frac{0.5R_1}{100\times\sqrt{3}} \qquad (11)$$

4.4 Evaluating the relative standard uncertainty of resolution, u_4

the standard uncertainty related to the resolution error of the calibrated device is calculated in relative value by the following equations:

$$u_4 = \frac{r}{100 \times \sqrt{6}} \qquad (12)$$

where r is the resolution expressed as a relative value

4.5 Evaluating the relative standard uncertainty of residual deflection, u_5

the standard uncertainty related to the residual deflection error of the measured torque is calculated in relative value by the following equations:

$$u_5 = \frac{R_0}{100 \times \sqrt{3}} \qquad (13)$$

where r is the resolution expressed as a relative value

4.6 Evaluating the relative standard uncertainty of temperature effect, u_6

the standard uncertainty related to the variation of temperature throughout the calibration is calculated in relative value by the following equations:

$$u_6 = \frac{K \Delta t}{100 \times 2\sqrt{3}} \qquad (14)$$

where *K* is the torque device's relative temperature factor expressed as a percentage of maximum applied torque per degree Celsius, derived either by tests or from the manufacturer's specifications;

4.7 Evaluating the relative standard uncertainty of interpolation error, u_7

the standard uncertainty related to interpolation error of the measured torque is calculated in relative value by the following equations:

$$u_7 = \frac{0.5 E_{it}}{100 \times \sqrt{6}} \qquad (15)$$

4.8 Evaluating the relative standard uncertainty of reversibility, u_8

the standard uncertainty related to reversibility error of the measured torque is calculated in relative value by the following equations:

$$u_8 = \frac{0.5 R_3}{100 \times \sqrt{3}} \qquad (16)$$

4.9 Evaluating combined and expanded standard uncertainty

According to BS 7882:2017 and GUM, the standard combined uncertainty (u_c) are calculated for all calibration points. The u_c is determined as the root square for the sum of the square of the previously contribution parameters using the equation (9). The expanded uncertainty can be obtained by reproduce u_c by coverage factor (k=2) at 95% confidence level.

$$u_c = \sqrt{\sum_{i=1}^{n} u_i^2} \qquad and \quad U = u_c \times K \qquad (17)$$

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5. SUGGESTION METHOD FOR CLASSIFICATION

The aim of this method is to classify the torque measuring considering all factors that might affect the classification principles. This will be carried out by estimating the expanded uncertainty budget of all factors affecting and consequently certifying the conformity between the BS 7882:2017 and the international standard for accreditation ISO/IEC 17025:2017. During this method, the relative errors values in Table 2 is used to calculate the uncertainty budget at each class. All the impacting factors were collective with the percentage of their influence in the expanded uncertainty to re-determine the classification method created on the uncertainties calculated and not on the relative error values (see Tab. 1). The BS 7882:2017 standard finds the uncertainty mechanisms considered in equations from 10 to 16 their uncertainty values was mentioned in Table 2.

Table 2 Uncertainty components determined for the suggested method.

Class	**Relative uncertainty of torque devices (%)**							**Standard uncertainty u_1 (%)**
	Repeatability u_3	**Reproducibility u_2**	**Interpolation u_7**	**Residual u_5**	**Reversibility u_8**	**Indication u_7**	**Resolution u_4**	
0.05	0.0000521	0.0003125	0.0000260	0.0000083	0.0003203	0.0000521	0.0001125	0.0005
0.1	0.0002083	0.0012500	0.0001042	0.0000333	0.0013021	0.0002083	0.0002514	0.0005
0.2	0.0008333	0.0050000	0.0004167	0.0001333	0.0052083	0.0008333	0.0001254	0.0005
0.5	0.0052083	0.0312500	0.0026042	0.0008333	0.0125521	0.0052083	0.0011217	0.0005
1.0	0.0208333	0.1250000	0.0104167	0.0033333	0.1002083	0.0208333	0.0144340	0.0005
2.0	0.0833333	0.5000000	0.0416667	0.0133333	0.5208333	0.0833333	0.0288680	0.0005
5.0	0.5208333	2.1250000	0.2604167	0.0833333	3.2552083	0.5208333	0.0577350	0.0005

6. RESULTS AND DISCUSSION

Equation (17) is used to determine the expanded uncertainty budget taking into account the coverage factor 2 with confidence level 95%. The suggested method is created on exploiting the uncertainty of the calibration results of torque devices as decision rule for the devices classifications to be in the same line with ISO/IEC 17025:2017.

The uncertainty budget must be assessed and all uncertainty components required to be calculated. Equation from (10) – (16) were used to determine every standards uncertainty. The summarized uncertainty was determined using equation (17). The uncertainty parameters are concise separate in table 2.

Table 3 Uncertainty components determined for the suggested method.

Class	The combined uncertainty for all parameters (%)	Expanded Uncertainty of the torque device with confidence level 95% (Uexp)
0.05	0.029730	0.059461
0.1	0.057945	0.115891
0.2	0.112029	0.224057
0.5	0.242442	0.484883
1.0	0.543193	1.086387
2.0	1.127550	2.255099
5.0	2.612156	5.224312

The combined and expanded uncertainties are mentioned in table 3. Once the uncertainty components are considered by two hundredths, the results are exposed in table 4. According to the suggested results shown in table 3. The classifications factors are stated in table 4. The expanded uncertainty budget of the torque devices was determined according to the equations mentioned above where it is corresponding to all the contributed parameters. Therefore, it is conceivable to set matching values for each class as the values of the uncertainty in table 4, which is determined from every subscribed component. The values of uncertainty can be measured congruent to each class and it is the limit for each class. Consequently, there is agreement between the standards ISO 17025:2017 and BS7882:2017, as seen in table 5. The values of expanded uncertainty were stated in two hundredths.

Table 4 Suggestion classification criteria

Class	Expanded uncertainty of the torque device with confidence level 95% (U_{exp})
0.05	0.05
0.1	0.10
0.2	0.25
0.5	0.75
1.0	1.25
2.0	2.25
5.0	5.50

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Table 5 bounders of torque device for BS 7882-2017 compared with suggested method.

Class	Permissible relative values %							Suggested Classification criterion, Expand Uncertainty of the torque devices at 95%confidrnce level.
	u_3	u_2	u_7	u_5	u_8	Indication error, u_8	Reference Uncertainty u_1.	
0.05	0.025	0.05	0.025	0.01	0.062	0.025	0.0005	0.05
0.1	0.05	0.1	0.05	0.02	0.125	0.05	0.0005	0.10
0.2	0.1	0.2	0.1	0.04	0.25	0.1	0.0005	0.25
0.5	0.25	0.5	0.25	0.1	0.625	0.25	0.0005	0.75
1.0	0.5	1	0.5	0.2	1.25	0.5	0.0005	1.25
2.0	1	2	1	0.4	2.5	1	0.0005	2.25
5.0	2.5	5	2.5	1	6.25	2.5	0.0005	5.50

7 CONCLUSION

Uncertainty in metrology has become the main aspect in the various decision-making situations that currently stand in metrology. Therefore, the recently issued ISO/IEC 17025 standard requires a condition that uncertainty is the law of decision-making such as success or fail…..etc. In the study, a method is proposed to modify the classification of torque apparatus mentioned in BS 7882:2017. This proposed method has been raised to align the classification standard for the upcoming new release of BS 7882:2017 for calibrating torque apparatus to comply with the requirements of ISO/IEC 17025. Based on this study the uncertainty can be used as one factor in classifying torque devices, where the uncertainty is the grouping of different components that may affect the outcome of the instruments. So it is more accurate and comprehensive to be the basic rule for classifying these instrument.

The proposed classification criterion should take into account the uncertainty of the calibration results. This proposal is very important for manufacturers of torque apparatus to establish that the uncertainty is responsible for the quality level of the measuring apparatus. In this paper, a proposal is developed to classify torque gauges using uncertainty as a foundation for the classification decision. To confirm this suggestion, the torque calibration results were used. It is important that this torque transducer is calibrated according to BS 7882:2017. It has been concluded that it is recommended to reconsider the classification of torque measuring apparatus, taking into account uncertainty budget calculations. It is possible to suggest future research based on this investigation considering various risk situations such as customer risks and product risks that have been investigated separately.

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