Development of a Standard Practice for the Calibration of Torque-Measuring Instruments for Verifying the Torque Indication of Testing Machines

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ABSTRACT

The American Society for Testing and Materials International (ASTM), has over 11,000 testing standards. It is made up of committee members from the industry, government, and universities.

ASTM Subcommittee E28.01 on Calibration of Mechanical Testing Machines and Apparatus has started development of a Standard Practice for the calibration of torque indicating devices used as reference standards when verifying the torque indication of testing machines. This paper concentrates on that effort.

The paper discusses the process from conception through the drafting process to the development of the working document. A round robin testing program involving a number of torque transducer manufacturers and providers of torque calibration services was initiated and some results are presented in this paper.

INTRODUCTION

Many users of material testing machines world wide rely on ASTM developed testing methods and standards to guide them in performing material tests and establishing material properties. Testing performed with modern materials testing machines provide confidence in the safety and reliability of many materials and components used by the transportation industry, the medical industry, and by consumer product suppliers that range from infant car seats to asphalt. For this reason, the calibration of testing machines and testing machine devices is critical to the traceability and credibility of testing machine performance and testing results. Laboratory accreditation pressures add important emphasis on the need for verifiable measurement uncertainty related to testing results. Testing machines have become increasingly more complex and versatile. Software packages have been developed to assist the testing laboratory in the determination of many material properties under a much wider range of applied physical conditions. Many testing machines are now being used to apply and measure torsional forces exerted on a specimen or component.

The ASTM E28.01 subcommittee is currently responsible for the following standards, the Standard Practice of Calibration of Force-Measuring Instruments for Verifying the Force Indication of Testing Machines (E74)[(1)], the Standard Practices for Force Verification of Testing Machines (E4)[(1)], and the Standard Practice for Verification and Classification of Extensometers (E83)[(1)]. These standard practices provide the primary measurement traceability for the testing system when measuring and indicating axial stress and strain. Two very important measurement components when determining material properties and reliability.

In keeping with our charter to support testing machines in the area of calibration and verification, the E28.01 subcommittee has drafted two new Standard Calibration Practices. The Standard Practice of Calibration of Torque-Measuring Instruments for Verifying the Torque Indication of Torque Testing Machines and the Standard Practice for Torque Verification of Torque Testing Machines and Devices. This paper concentrates on the efforts related to the first of these listed standard practices covering Torque-Measuring Instruments.

It was decided that the ASTM E74 Standard Practice covering Force-Measuring Instruments would serve as the template for the new torque calibration standard. A draft standard was written and reviewed. It was acknowledged that at least two European standards were already available and should be examined as we develop the ASTM version.

The subject of validating the standard was important as we started our development efforts. We questioned whether the E74 practice was sufficiently equivalent for calibration of torque devices to expect the same results related to precision and bias that we had on record from studies conducted using the force calibration practice. A number of us did not feel comfortable with this based on previous experiences with suppliers of torque transducers and calibration suppliers. A round robin testing program was suggested in an attempt to validate the standard. A representative from the National Association for Proficiency Testing (NAPT) volunteered to facilitate the testing. MTS Systems Corporation provided the artifact standard and indicator. An individual from the MTS Metrology department would act as technical advisor. It took just over a year to get 9 laboratories completely through the testing program.

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(1) Annual Book of ASTM Standards, Vol. 03.01.

Upon our initial investigation into developing the round robin testing program we found that the National Institute of Standards and Technology (NIST) does not provide calibration services for torque measuring devices. This presented a problem because for our round robin test it was important to have an established reference laboratory to calibrate our artifact. Luckily an ASTM member from HBM(2) was able to obtain assistance from PTB(3) to act as reference laboratory for our testing. We not only were now able to compare our results to an established reference laboratory but we also could compare our round robin testing results with results obtained using a different standard. PTB would use the DIN 51309(4) standard when calibrating our artifact.

Comparing European Standards

When researching alternative published standards I reviewed BS7882(5), and DIN 51309. Both of these standards in my opinion are excellent standards for the calibration of torque measuring devices. There are some differences between the European standards and the proposed ASTM standard. These differences are much like the differences between the ASTM calibration standards for the Calibration of Force-Measuring Instruments, and European standards for the calibration of Force Indicating Devices.

The BS 7882 standard provides for six levels of classification ranging from 0.1 to 5.0. The DIN 51309 standard provides for seven levels of classification ranging from 0.05 to 5.0. The ASTM standard provides for only two levels of classification, Class AA (0.05) and Class A (0.25). The primary reason for the large difference in the number of levels of classification between the European standards and ASTM is because Material Testing Machines calibrated to current European standards are classified to multiple classifications where as Material Testing Machines calibrated to the ASTM standard meet only one set of classification criteria.

ASTM Class AA devices are typically used as secondary reference standards. The measurement uncertainty of a Class AA device must not exceed 0.05% of the moment torque. The lower torque limit of the instrument is defined as 2000 times the uncertainty, in torque units, obtained from the calibration data.

ASTM Class A devices are typically used for verifying torque testing machines. The measurement uncertainty of a Class A device must not exceed 0.25% of the moment torque. The lower torque limit of the instrument is defined as 400 times the uncertainty, in torque units, obtained from the calibration data.

The European standards provide for classification of devices other than elastic calibration devices for the calibration of testing machines. These devices may include torque sensors use

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(2) Hottinger Baldwin Messtechnik GmbH

(3) Physikalisch-Technische Bundesanstalt, Braunschweig und Berlin

(4) DIN 51309, Calibration of static torque measuring devices

(5) BS 7882, Method for Calibration and classification of torque measuring devices

in torque tools. The ASTM standard only provides classification for elastic calibration devices for calibration of testing machines and as reference standards.

I have included below the Classification Criteria for both European standards. You will see that although they are not identical, they are very similar in the criteria required for the specific classifications.

BS 7882 Classification Criteria[6]

Class	Maximum permissible error of the torque measuring device %					
	Relative Error of repeatability	Relative Error of reproducibility	Relative error of interpolation	Relative error of zero	Relative error of reversibility	Relative error of indication
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

Uncertainty of calibration torques[7]	
Class of torque measuring device to be calibrated	**Maximum permissible uncertainty of calibration torque applied (BS 7882)**
0.1	± 0.02
0.2	± 0.04
0.5	± 0.10
1.0	± 0.20
2.0	± 0.40
5.0	± 1.00

(6) BS 7882, Table 3
(7) BS 7882, Table 1

DIN 51309 Classification Criteria[8]

	Maximum permissible error of the torque measuring device in %						Calibration Torque
Class	Relative reproducibility error	Relative repeatability error	Relative error of zero signal	Relative reversibility error	Relative error of indication or interpolation	Min. value of measurement range	Expanded rel. uncertainty of measurement in % (k=2)
0.05	0.05	0.025	0.0125	0.063	± 0.025	≥ 4000 r	0.010
0.1	0.10	0.05	0.025	0.125	± 0.05	≥ 2000 r	0.020
0.2	0.20	0.10	0.050	0.250	± 0.10	≥ 1000 r	0.040
0.5	0.50	0.25	0.125	0.63	± 0.25	≥ 400 r	0.10
1	1.0		0.25	1.25	± 0.5	≥ 200 r	0.20
2	2.0		0.50	2.50	± 1.0	≥ 100 r	0.40
5	5.0		1.25	6.25	± 2.5	≥ 40 r	1.0

(r = resolution)

The classification of a torque measuring instrument per the ASTM standard is based primarily on the standard deviation from the differences between the individual values observed in the calibration and the corresponding values taken from the calibration equation. The calibration equation is derived by fitting a polynomial equation to the torque and deflection values obtained in the calibration using the method of least squares. A 2nd degree equation is recommended. Other degree equations may be used. The standard provides an Annex for determination of the best degree fit polynomial.

Procedurally, the ASTM standard is very similar to the European standards. Care and attention is given to alignment and fixture issues. Requirements for monitoring and control of laboratory temperature during calibration is similar. The determination of resolution, the preload process, and application of torsional forces are also very similar.

One area where the ASTM standard departs from the requirements as specified by the European standards is that the ASTM standard does not require a repeat of calibration data with the device in an unchanged mounting position. It is recommended that each run of data obtained in the same loading direction be taken with the device rotated in the calibration fixture. Another point of difference between the ASTM standard and the European standards is that the ASTM standard does not set a time requirement for acquiring calibration data with torsional forces applied or when returning to zero and stabilizing before starting an additional run of calibration data. The European standards require a minimum of 30 seconds wait time with torque applied or after removal of torsional force before recording the output from the torque measuring device. The ASTM standard states that torque values shall be applied and removed slowly and smoothly, without inducing shock or vibration to the torque measuring instrument. The time interval between successive applications or removals of torque values, and in obtaining readings from the torque measuring instrument, shall be as uniform as possible. No specific wait time is recommended. With modern automated calibration

[8] DIN 51309, Table 3

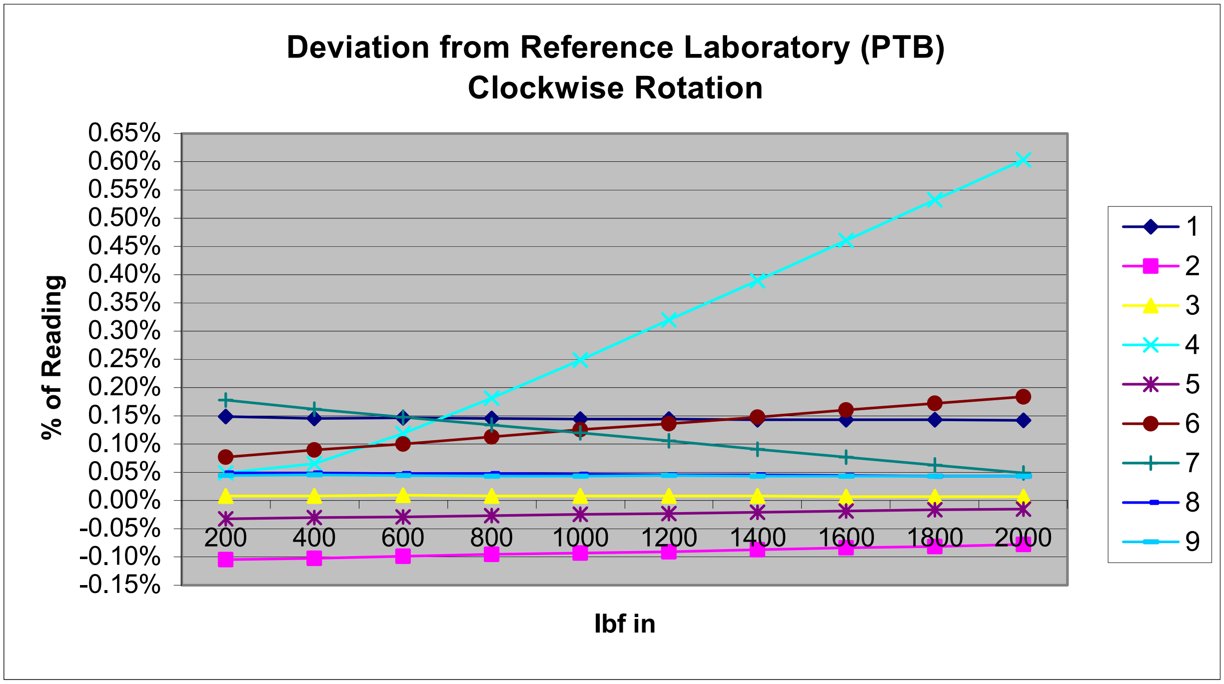
processes, it is my opinion that monitoring the stability of the torque instrument for determination of stability and drift while performing the calibration is a better way to perform the procedure. Limit controls related to change in instrument reading per second could be set in software to determine when the device has sufficiently stabilized in order that calibration data may be obtained. My experience is that 30 seconds is unnecessarily long.

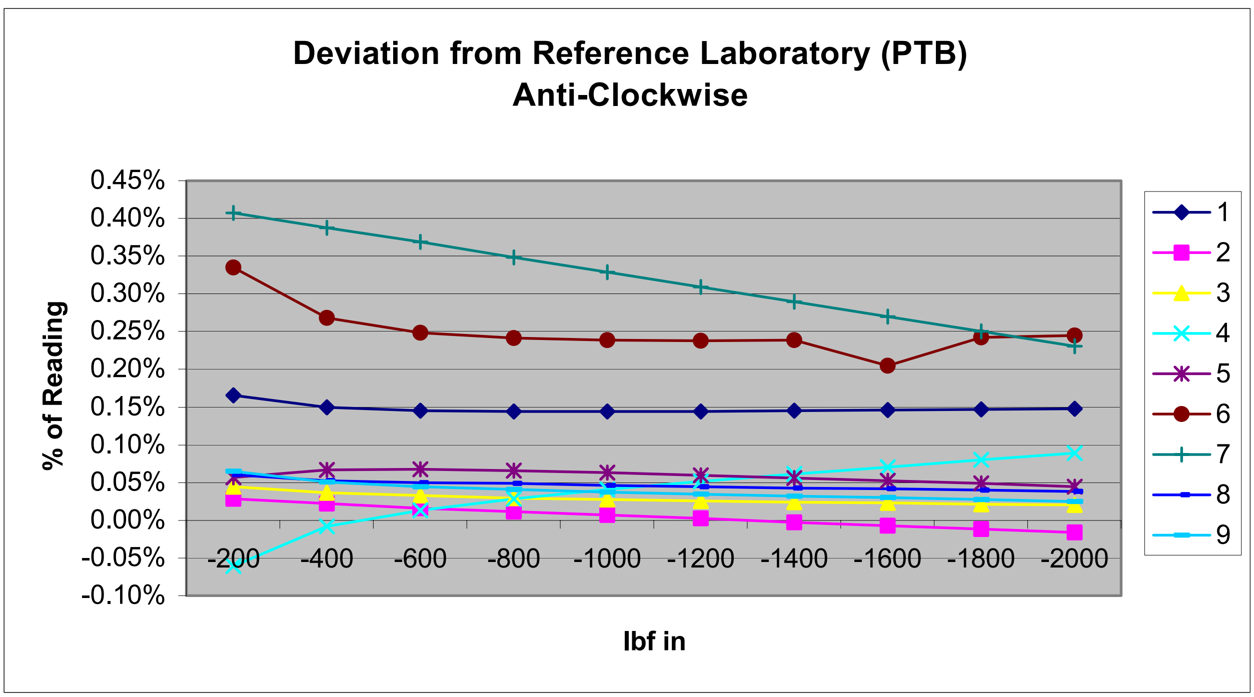
It is important when comparing these standards to realize that the ASTM standard is not a standard used to evaluate how well a torque measuring device is capable of performing. It is specific to providing reference and working standards for the calibration of testing machines.

The ASTM standard requires that all torque measuring instruments and systems used as secondary standards be calibrated or verified annually. The ASTM standard provides some guidance for lengthening the calibration intervals for devices used for calibration of testing machines. The standard states that these devices shall be calibrated 1 year after the first calibration and thereafter at intervals not exceeding 2 years, provided that the changes between the most recent calibration equation values and those from the previous calibration do not exceed 0.1% of the capacity torque deflection. BS 7882 states that the torque measuring device shall be recalibrated at least every 12 months and whenever it suffers any damage or has been subject to any repair. DIN 51309 states that the maximum period of validity of the calibration certificate shall not exceed 26 months. The torque measuring device shall be recalibrated when it is subjected to an overload higher than that applied in the overloading test after repair or after inexpert handling which may have an effect on the uncertainty of measurement. This is one of the areas related to all three standards that I think should be improved. There is basically no long term stability criteria included in these standards. Those who provide calibration for torque measuring devices will need to rely on their own defined stability criteria when evaluating an “as found” calibration condition. This is necessary in order to establish an intolerance or out of tolerance condition in compliance with acceptable calibration quality programs. This issue is currently on the agenda for an up coming ASTM committee meeting dealing with calibration standards.

Round Robin Test Results

The following graphs show the relationship between the predicted responses for each applied torque for 9 calibration laboratories and the reference laboratory’s (PTB) predicted responses for each applied torque.





The predicted responses from PTB show the torque measuring instrument to be very symmetrical in nature. A statement of measurement uncertainty was requested from each laboratory. Further investigation will be necessary to determine how influential each laboratory's estimated measurement uncertainty is on the resultant calibration data.

It is fairly apparent that Lab # 4 had some problems with the clockwise torque measurements. Laboratories 6 and 7 had some trouble with symmetry as reflected in greater errors in the anti-clockwise direction. There are four laboratories that I feel faired well. They are Labs 2,3,5 and 9. In assessing this data I am concerned with the magnitude of error that could be induced when calibrating a torque testing machine with the torque measuring instrument, if the instrument were calibrated by any of these laboratories. As well as the correlation of predicted response data to the reference laboratory, we need to examine the data scatter for each laboratory.

Preliminary Conclusions

These conclusions are preliminary because we have more work to do. I think the standard as written is a good start for it's intended purpose. It provides a standardized method for calibration of torque measuring instruments with out requiring a great deal of data handling. The round robin testing program shows that it is possible to reproduce data from one lab to another using this standard. I believe that those using the standard will benefit if measurement uncertainty criteria is required as it is in the European standards. I also feel that it is very important that criteria for long term stability be included in the standard. The next steps in this process will be addressed at the ASTM meeting in Pittsburgh, PA in May 2002.

Bibliography

[1] ASTM, Draft unpublished, Standard Practice of Calibration of Torque-Measuring Instruments for Verifying the Torque Indication of Torque Testing Machines

[2] BS 7882: 1997, Method for Calibration and classification of torque measuring devices

[3] DIN 51309: 1998-02, Materials testing machines, Calibration of static torque measuring devices

[4] NAPT Report, Physikalisch-Technische Bundesanstalt (PTB) Reference No: PTB-1.13_01-052