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# TEMPERATURE AND HUMIDITY DEPENDENCE ON STABILITY OF TORQUE MEASURING DEVICES

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**Abstract:** Effect of temperature and humidity on torque measuring devices were studied.With the aim to estimate measurement uncertainties due to environmental varying conditions, torque transfer wrenches and transducers were carried out by the measurement in an environmental controlled chamber under conditions of range 16ºC to 31ºC and 35 %RH to 65 %RH. The measurement responses from two kind of amplifiers, alternating current and direct current excitation amplifier were taken into account as well. The temperature sensitivity was significantly minimized causing by temperature compensation circuit. Moreover, the humidity sensitivities from several kinds of torque device structure consisted of directly contact to ambient, covering protection, waterproof protection and hermetically sealed seem to be similar and cannot be distinguished. On the other hand, amount of humidity sensitivity obtained by using direct current excitation amplifier are smaller than using alternating current excitation amplifier.

**Keywords:** Torque measuring devices, temperature sensitivity and humidity sensitivity

## 1. INTRODUCTION

National Institute of Metrology (Thailand) was requested to review uncertainty evaluation of torque measurement that one of quantities in ISO/IEC 17025 accreditation scope. Sources of measurement uncertainties are concerned including to the uncertainty due to environmental conditions such as temperature and humidity effect. Thus the temperature sensitivity and humidity sensitivity are necessary to known clearly. So these effects were studied.

The former research, “A Study of Torque Transfer Wrench Stability” [1] shows that an influence of temperature significantly affects the accuracy of torque transfer wrenches in case of on-site calibration, but using temperature compensation circuit can reduce these effect. However for humidity, the experimental results show that there is no significant difference on humidity sensitivity among different humidity protections of torque transfer wrench. Thus, the level of moisture absorption in strain gauge is not a dominant influence of instability of the transducer due to humidity. For this reason, how humidity affects the transducer should be deliberately studied and understood.

Principally, a bridge circuit of torque transducer is the main part to transform mechanical deformation to electrical signal. The circuit consists of electrical components, which are connector, cable, lead wire and strain gage. The researcher is interested in studying the humidity effect on electrical characteristic of the devices, in particularly the impedance of bridge circuit. To prove this hypothesis, torque measuring devices are sampled and measured repeatedly in order to compare temperature and humidity sensitivity from using two types of amplifier: alternating current (AC) excitation amplifier and direct current (DC) excitation amplifier. In case different measurement results for different devices with humidity sensitivity, it is affirmed that the impedance characteristic of circuit causes the humidity effect.

To ensure that high accuracy torque transducers, one of torque measuring devices, have been tested under the same condition as torque transfer wrenches, high accuracy torque transducers are also under experiment as well.

## 2. IMPEDANCE IN BRIDGE CIRCUIT

Normally strain gauge bridge circuit is a simple resistance circuit as shown in Fig. 1. The excitation voltage is stabilized by feedback control system; although there is voltage across the resistances pertained to cables.

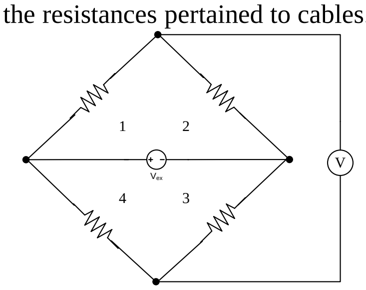



**Fig. 1,** Strain gauge bridge circuit

The output signal of bridge circuit equals to $\Delta R / R$, when the supply voltage is DC. On the other hand when the supply voltage is AC, impedance in strain gauge bridge circuit should be included in calculation. The impedance consists of resistance, inductance and capacitance.

Inductance equation is described in equation (1),

$$L = \mu_0 \mu_r N^2 \frac{A}{l} . \quad (1)$$

Where $L$ denotes the inductance, $\mu_0$ denotes the magnetic constant ($4\pi\times10^{-7}$ H/m), $\mu_r$ denotes the relative permeability, $N$ denotes the number of turns, $A$ denotes the cross-section area and $l$ denotes length of the coil.

Capacitance equation is described in Equation 2;

$$C = \varepsilon_r \varepsilon_0 \frac{A}{d}. \quad (2)$$

Where $C$ denotes the capacitance, $A$ denotes the area of overlap of the two plates, $\varepsilon_r$ denotes the relative static permittivity, $\varepsilon_0$ denotes the electric constant ($\varepsilon_0 \approx 8.854\times10^{-12}$ F m$^{-1}$) and $d$ denotes the separation between the plates.

Considering the phase relationship, the origin of the different signs for capacitive and inductive reactance is the phase factor in the impedance;

$$Z_C = -j\left(\frac{1}{\omega C}\right) \quad (3)$$

and $$Z_L = j\omega L. \quad (4)$$

Where $Z_C$ denotes the capacitive reactance, $Z_L$ denotes the inductive reactance, $j = \sqrt{-1}$ and $\omega$ denotes the angular frequency.

The simple impedance bridge circuit is shown in Fig. 2(a) and equivalent circuit is shown in Fig. 2(b). From the equation (1) and (2), the impedance of circuit depends on humidity, but for DC supply voltage the inductance and capacitance can be negligible. This difference of the circuits may cause the different output signals.

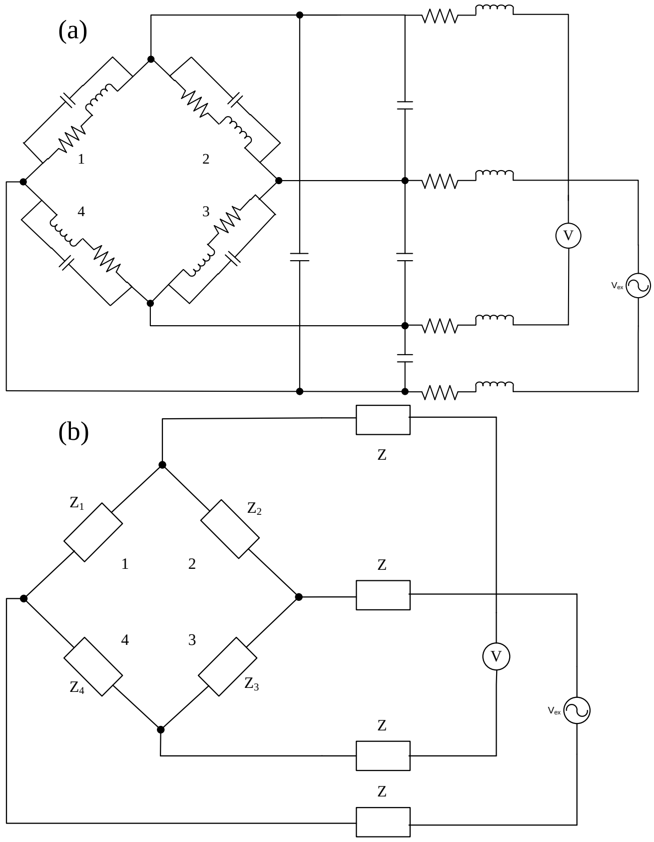



**Fig. 2**, a) the simple impedance bridge circuit and b) the equivalent impedance bridge circuit.

## 3. EXPERIMENTAL SETUP

In the experiment, torque measuring devices and amplifiers are set up and left in environmental controlled chamber in order to ensure identical of temperature and humidity absorption of the two devices and the environment is controlled as same situation as real application. The environmental controlled chamber produces by Airplus Apply Co., Ltd. It has a capacity of 8 m$^3$. The stability of temperature control is ± 0.3°C and humidity control is ± 1 %RH. Furthermore, to ensure that the devices and amplifiers are saturated by temperature and humidity, they have been left in controlled conditions at least 4 hours before measurement process begins

The environmental conditions are;

1) To study on temperature stability, temperature is controlled between 16°C – 28°C at 50 %RH constant humidity.
2) To study on humidity stability, humidity is controlled between 35 %RH - 65 %RH at 22°C constant temperature.

The measurement points are approximately 0%, 50% and 100% of torque capacity. Torque is applied by direct weight loading on a constant distance of arm length of torque transfer wrench itself. For torque transducer, torque is applied from weight loading to lever arm fabricated as shown in Fig. 3.

## 4. TORQUE MEASURING DEVICES

For this research, torque transfer wrenches (TTW) and high accuracy torque transducers (TTS) have various structures, but can be classification by;

– Bridge circuit types: with temperature compensation circuit and without temperature compensation circuit.
– Humidity protection: hermetically sealed, water proof protection, open housing with protective covering on strain gauge and open housing with strain gauge directly contacted to an ambient humidity.

4.1 Commercial TTW Model: TTS, capacity: 50 N m S/N: 014640002, manufactured by HBM, Germany. Where sensing body is open housing type with radial shear design. Temperature compensation and protective coverings of full bridge circuit strain gauges are employed.

4.2 Commercial TTW Model: DmTS, capacity: 20 N m S/N: 48039, manufactured by GTM, Germany. Where sensing body is open housing type with bending design. Temperature compensation and protective coverings of full bridge circuit strain gauges are employed.

4.3 Commercial TTW Model: TTW 10, capacity: 10 N m S/N: TTW 101, manufactured by CEH, Germany. Where sensing body is open housing type with bending design. Protective coverings of full bridge circuit strain gauges were employed but no temperature compensation is furnished.

4.4 Fabricated TTW Model: Chock 03, capacity: 50 N m S/N:03.04.2551, fabricated by NIMT. Where sensing body is open housing type with bending design, without temperature compensation and protective coverings of full bridge circuit strain gauges.

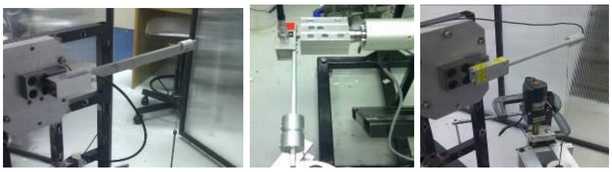
4.5 Fabricated TTW Model: Chock 04, capacity: 50 N m S/N: 290910, fabricated by National Institute of Metrology (Thailand), NIMT. Where sensing body was design based on the principle of load cell application in torque [2]. Temperature compensation and protective coverings of full bridge circuit strain gauges are employed.

4.6 Fabricated TTW Model: Chock 05, capacity: 200 N m S/N: 020910, fabricated by NIMT. Where sensing body is hermetically sealed type hollow shaft design, without temperature compensation and protective coverings of full bridge circuit strain gauges [3].

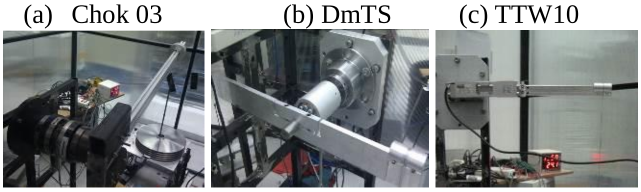
4.7 Commercial TTS Model: DmTN, capacity: 20 N m S/N: 57340, manufactured by GTM, Germany. Where sensing body is open housing type with solid shaft design. Temperature compensation and waterproof protection of full bridge circuit strain gauges are employed.

4.8 Commercial TTS Model: TT1/10 N m, capacity: 10 N m S/N: 36838-04, manufactured by Raute Precision Oy. Where sensing body is open housing type with solid shaft design. Temperature compensation and protective coverings of full bridge circuit strain gauges are employed.

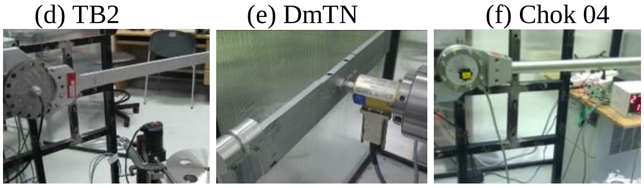
4.9 Commercial TTS Model: TB2/1000 N m, capacity: 1,000 N m S/N: #120730044, manufactured by HBMr, Germany. Where sensing body is hermetically sealed type axial shear principle design, Temperature compensation is employed.



(a) Chok 03 (b) DmTS (c) TTW10



(d) TB2 (e) DmTN (f) Chok 04



(g) Chok 05 (h) TT1 (i) TTS

**Fig. 3,** Experiment setup of each torque measuring devices.

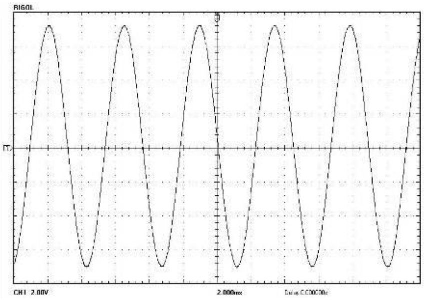
## 5. AMPLIFIERS

The experiment was set up with 2 amplifiers as followings.

5.1 Alternating current excitation amplifier, model: MGC Plus with measurement card model: ML38 and ML 30, manufactured by HBM, S/N: 801058930. AC excitation voltage 5 $V_{rms}$, frequency 225.05 Hz and 600 Hz for ML38 and ML30 respectively are shown in Fig. 4(a) and 4(b).

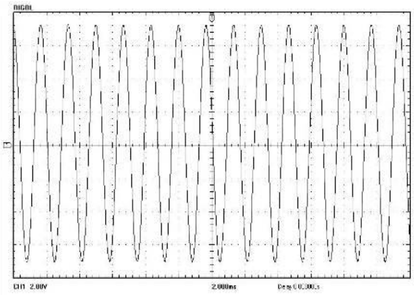
5.2 Direct current excitation amplifier, manufacture by GTM, model: VN, S/N: CKDB3J015. Accuracy of class 0.001 with DC excitation voltage 10 VDC as shown in Fig. 4(c).

(a)



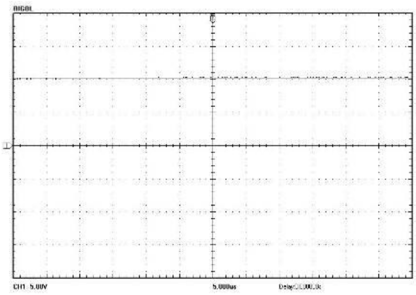
2.0 volt/div., 2.0 ms/div.

(b)



2.0 volt/div., 2.0 ms/div.

(c)



5.0 volt/div., 5.0 µs/div.

**Fig. 4,** Show the supply voltage signal of a) and b) AC excitation amplifier with measurement card ML38 and ML30 respectively, and c) DC excitation amplifier.

All of torque measuring devices are measured by AC excitation amplifier and some of torque measuring devices (TTS model: TB2, TTS model: TT1, TTS model: DmTN, TTW model: Chock 03 and TTW model: TTW10) are also re-measured by DC excitation amplifier.

## 6. TEMPERATURE EFFECT

Temperature stability is used to calculate temperature sensitivity and standard deviation in the form of absolute value and relative value described in Table 1. From the results, there is consistency of the relative value of sensitivity at 50% increasing, 50% decreasing and 100% of capacity as shown in Fig. 5. Therefore, temperature sensitivity should be described in term of relative value.

**Table 1:** The temperature sensitivity obtained by using AC excitation amplifier.

| Torque Measuring Devices | Parameter | Temperature effect (mV/V)/K Sensitivity | Temperature effect (mV/V)/K SD. | Temperature effect %/K Sensitivity | Temperature effect %/K SD. |
|---|---|---|---|---|---|
| TTS [1] | *Noload* | 4.9E-04 | 4.5E-05 | 6.2E-02 | 5.7E-03 |
| | *50%inc.* | -1.9E-05 | 2.8E-06 | -4.9E-03 | 7.2E-04 |
| | *100%* | -4.0E-05 | 4.9E-06 | -5.1E-03 | 6.3E-04 |
| | *50%dec.* | -1.8E-05 | 3.1E-06 | -4.6E-03 | 7.8E-04 |
| | *f0* | 6.0E-07 | 5.5E-07 | 7.6E-05 | 7.0E-05 |
| | *h* | 1.5E-06 | 1.1E-06 | 3.8E-04 | 2.8E-04 |
| DmTS [2] | *Noload* | 9.7E-05 | 4.4E-06 | 5.9E-03 | 2.7E-04 |
| | *50%inc.* | 6.8E-05 | 3.0E-06 | 8.2E-03 | 3.6E-04 |
| | *100%* | 1.4E-04 | 5.8E-06 | 8.2E-03 | 3.5E-04 |
| | *50%dec.* | 6.2E-05 | 2.8E-06 | 7.6E-03 | 3.3E-04 |
| | *f0* | -2.2E-06 | 2.4E-06 | -1.3E-04 | 1.4E-04 |
| | *h* | -5.4E-06 | 1.5E-06 | -6.5E-04 | 1.8E-04 |
| TTW10 [2] | *Noload* | 6.5E-05 | 4.1E-06 | 9.7E-03 | 6.1E-04 |
| | *50%inc.* | 2.1E-04 | 2.0E-06 | 6.4E-02 | 5.9E-04 |
| | *100%* | 4.3E-04 | 4.4E-06 | 6.3E-02 | 6.5E-04 |
| | *50%dec.* | 2.1E-04 | 2.0E-06 | 6.4E-02 | 6.0E-04 |
| | *f0* | 7.0E-08 | 1.8E-07 | 1.0E-05 | 2.7E-05 |
| | *h* | -4.2E-07 | 4.2E-07 | 9.9E-01 | 9.8E-01 |
| Chok 03 [2] | *Noload* | 6.7E-04 | 9.2E-06 | 4.9E-02 | 6.7E-04 |
| | *50%inc.* | 2.6E-04 | 2.9E-06 | 3.9E-02 | 4.3E-04 |
| | *100%* | 5.2E-04 | 5.9E-06 | 3.8E-02 | 4.3E-04 |
| | *50%dec.* | 2.6E-04 | 2.0E-06 | 3.8E-02 | 3.0E-04 |
| | *f0* | -5.1E-07 | 7.5E-07 | -3.7E-05 | 5.5E-05 |
| | *h* | -3.9E-06 | 1.5E-06 | -1.5E+00 | 5.6E-01 |
| Chok 04 [2] | *Noload* | -2.7E-05 | 6.3E-06 | -2.8E-03 | 6.5E-04 |
| | *50%inc.* | -5.0E-06 | 5.0E-06 | -1.0E-03 | 1.0E-03 |
| | *100%* | -1.3E-05 | 9.6E-06 | -1.3E-03 | 9.9E-04 |
| | *50%dec.* | -3.1E-06 | 4.7E-06 | -6.5E-04 | 9.7E-04 |
| | *f0* | 5.8E-07 | 7.5E-07 | 6.1E-05 | 7.7E-05 |
| | *h* | 1.7E-06 | 2.8E-06 | 3.5E-04 | 5.8E-04 |
| Chok 05 [2] | *Noload* | -2.5E-05 | 2.4E-06 | -4.0E-03 | 3.9E-04 |
| | *50%inc.* | 1.0E-04 | 2.0E-06 | 3.3E-02 | 6.3E-04 |
| | *100%* | 2.0E-04 | 2.6E-06 | 3.3E-02 | 4.2E-04 |
| | *50%dec.* | 1.0E-04 | 1.8E-06 | 3.2E-02 | 5.6E-04 |
| | *f0* | -7.7E-07 | 3.5E-07 | -1.2E-04 | 5.5E-05 |
| | *h* | -1.5E-06 | 1.2E-06 | -4.7E-04 | 3.8E-04 |
| DmTN [2] | *Noload* | 1.7E-05 | 1.0E-06 | -2.2E-03 | 1.3E-04 |
| | *50%inc.* | 2.4E-05 | 5.8E-07 | -6.2E-03 | 1.5E-04 |
| | *100%* | 5.0E-05 | 1.1E-06 | -6.3E-03 | 1.3E-04 |
| | *50%dec.* | 2.4E-05 | 8.0E-07 | -6.2E-03 | 2.0E-04 |
| | *f0* | 3.4E-07 | 1.8E-07 | -4.3E-05 | 2.3E-05 |
| | *h* | 1.5E-07 | 2.9E-07 | -7.3E-02 | 1.4E-01 |
| TT1 [2] | *Noload* | 4.1E-05 | 3.8E-06 | 3.8E-03 | 3.6E-04 |
| | *50%inc.* | 2.7E-05 | 1.7E-06 | 5.0E-03 | 3.2E-04 |
| | *100%* | 4.7E-05 | 3.0E-06 | 4.4E-03 | 2.8E-04 |
| | *50%dec.* | 2.4E-05 | 1.9E-06 | 4.4E-03 | 3.5E-04 |
| | *f0* | 2.4E-08 | 1.7E-07 | 2.3E-06 | 1.6E-05 |
| | *h* | -3.0E-06 | 1.0E-06 | -2.7E+00 | 9.3E-01 |
| TB2 [2] | *Noload* | 3.9E-06 | 3.2E-07 | 7.8E-04 | 6.4E-05 |
| | *100%* | 1.8E-05 | 3.0E-07 | 3.6E-03 | 6.0E-05 |
| | *f0* | -4.8E-08 | 8.6E-08 | -9.6E-06 | 1.7E-05 |

Note: This measurement results are without compensation of coefficient of linear thermal expansion (CTE) of lever arm;

[1] Made of stainless steel, CTE is 1.73 × $10^{-3}$ %/K,

[2] Made of aluminum, CTE is 2.38 × $10^{-3}$ %/K

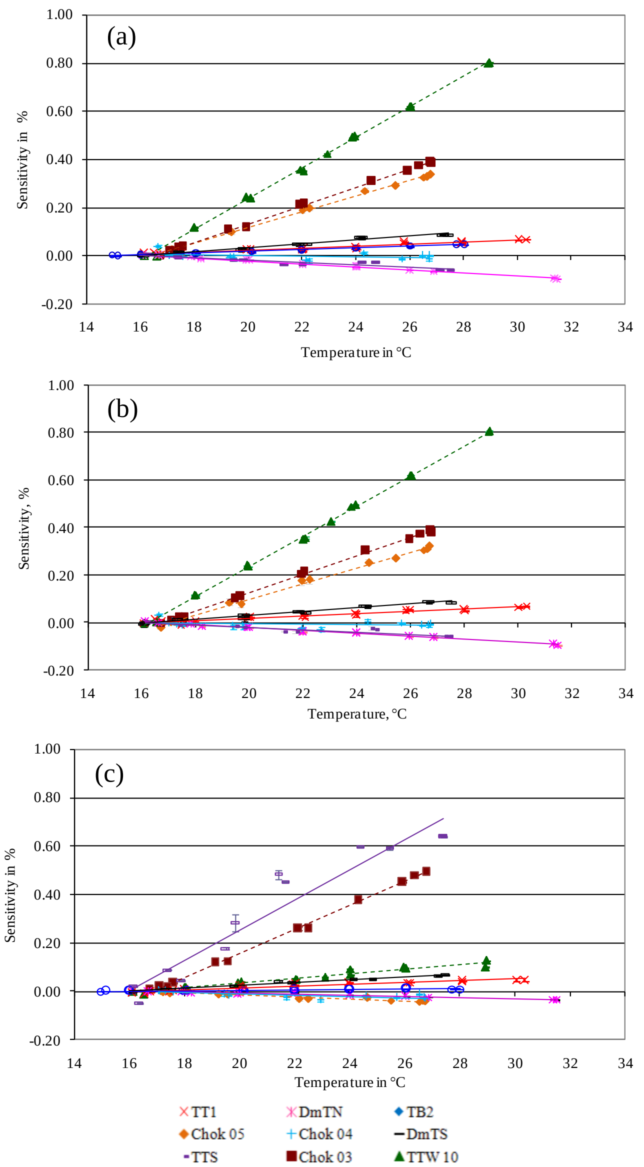



**Fig. 5,** Temperature stability on a) 100%, b) 50% of applied torque, and c) no load signal

- - - - - represent no temperature compensation

———— represent temperature compensation.

Stability of temperature for torque measurement have been classified to torque measuring devices without temperature compensation and with temperature compensation as shown in Fig. 6.

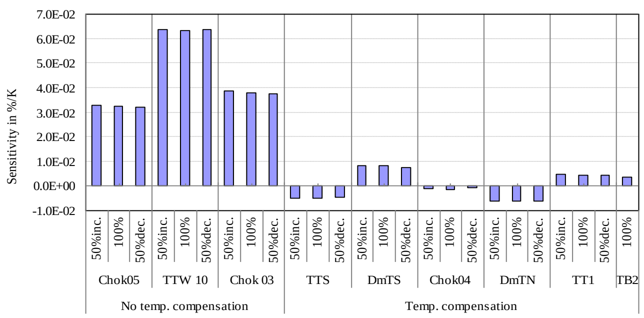



**Fig. 6,** Temperature stability of torque measuring devices classified by temperature compensation.

The stability of torque measuring devices without temperature compensation circuit are obviously affected by temperature with the sensitivity on temperature between 0.033 %/K to 0.066 %/K. These sensitivity is related to temperature expansion coefficient on gauge factor of strain gauge and Young's modulus of sensing body material.

While for torque measuring devices with temperature compensation, the sensitivity is between 0.00012 %/K to 0.0035 %/K, which is one tenth of the previous groups. However, temperature compensation technique of commercial torque transducers is inadequate for other activities requiring greater temperature stability such as measurement comparison.

## 7. HUMIDITY EFFECT

Humidity sensitivity and standard deviation are described in Table 2 and Fig. 7, the results of AC excitation amplifier.

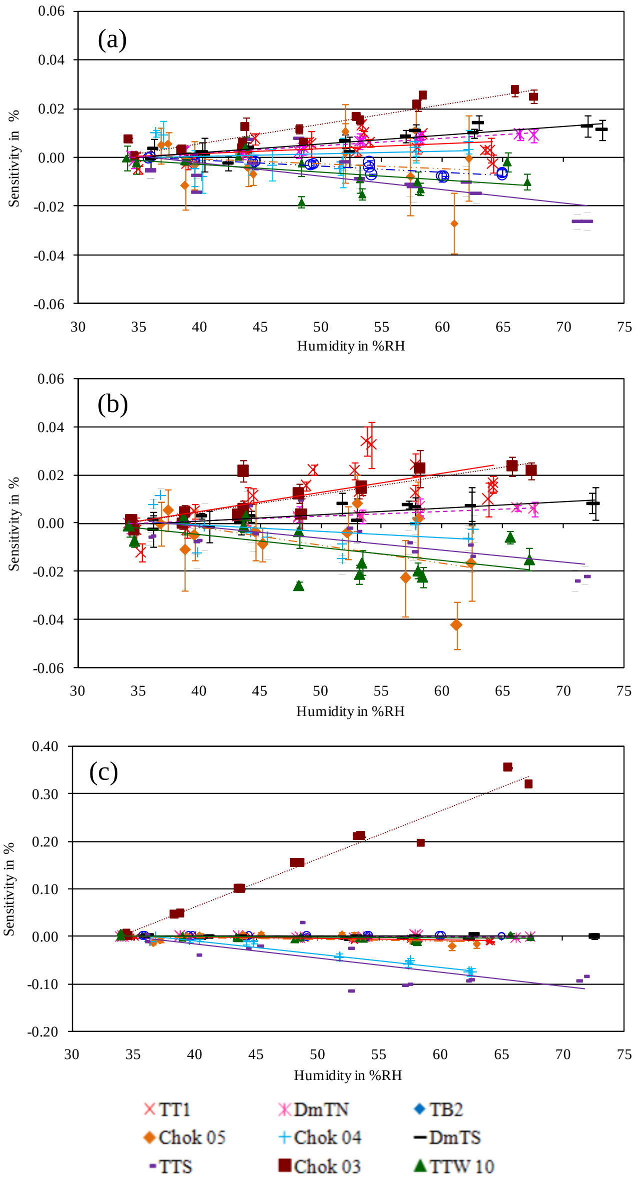



**Fig. 7,** Humidity stability on a) 100%, b) 50% of applied torque, and c) no load signal

............... represent no protective covering
______ represent protective covering
- - - - - represent waterproof protection
_ . . _ . represent hermetically sealed

**Table 2:** The humidity sensitivity obtained by using AC excitation amplifier.

| Torque Measuring Devices | Parameter | Humidity effect (mV/V)/%RH Sensitivity | Humidity effect (mV/V)/%RH SD. | Humidity effect %/%RH Sensitivity | Humidity effect %/%RH SD. |
|---|---|---|---|---|---|
| TTS i) | *Noload* | -2.3E-05 | 5.9E-06 | -3.0E-03 | 7.5E-04 |
| | *50%inc.* | -1.9E-06 | 6.2E-07 | -4.9E-04 | 1.6E-04 |
| | *100%* | -4.4E-06 | 1.3E-06 | -5.6E-04 | 1.7E-04 |
| | *50%dec.* | -3.2E-06 | 6.7E-07 | -8.0E-04 | 1.7E-04 |
| | *f0* | -3.9E-07 | 1.5E-07 | -5.0E-05 | 1.9E-05 |
| | *h* | -1.2E-06 | 2.5E-07 | -3.0E-04 | 6.4E-05 |
| DmTS ii) | *Noload* | 1.6E-07 | 1.1E-06 | 9.8E-06 | 6.5E-05 |
| | *50%inc.* | 2.2E-06 | 4.1E-07 | 2.6E-04 | 4.9E-05 |
| | *100%* | 6.0E-06 | 9.5E-07 | 3.7E-04 | 5.8E-05 |
| | *50%dec.* | 1.9E-06 | 6.2E-07 | 2.3E-04 | 7.6E-05 |
| | *f0* | -5.9E-07 | 3.7E-07 | -3.5E-05 | 2.3E-05 |
| | *h* | -6.2E-07 | 5.2E-07 | -7.6E-05 | 6.3E-05 |
| TTW10 ii) | *Noload* | -1.1E-06 | 8.0E-07 | -1.6E-04 | 1.2E-04 |
| | *50%inc.* | -1.8E-06 | 7.5E-07 | -5.4E-04 | 2.3E-04 |
| | *100%* | -2.2E-06 | 1.0E-06 | -3.2E-04 | 1.6E-04 |
| | *50%dec.* | -9.9E-07 | 7.5E-07 | -3.0E-04 | 2.2E-04 |
| | *f0* | 4.3E-08 | 5.3E-08 | 6.4E-06 | 7.9E-06 |
| | *h* | 3.2E-07 | 2.0E-07 | -5.0E+00 | 3.0E+00 |
| Chok 03 ii) | *Noload* | 1.4E-04 | 7.0E-06 | 1.0E-02 | 5.1E-04 |
| | *50%inc.* | 5.1E-06 | 9.3E-07 | 7.5E-04 | 1.4E-04 |
| | *100%* | 1.1E-05 | 1.2E-06 | 8.0E-04 | 8.7E-05 |
| | *50%dec.* | 4.3E-06 | 8.9E-07 | 6.4E-04 | 1.3E-04 |
| | *f0* | 3.6E-07 | 1.4E-07 | 2.6E-05 | 1.0E-05 |
| | *h* | -3.9E-07 | 8.8E-07 | -1.6E-01 | 3.6E-01 |
| Chok 04 ii) | *Noload* | -2.7E-05 | 2.0E-06 | -2.8E-03 | 2.1E-04 |
| | *50%inc.* | -1.2E-06 | 1.1E-06 | -2.6E-04 | 2.3E-04 |
| | *100%* | 9.3E-07 | 1.9E-06 | 9.7E-05 | 2.0E-04 |
| | *50%dec.* | 3.7E-07 | 1.0E-06 | 7.7E-05 | 2.2E-04 |
| | *f0* | 1.7E-07 | 2.7E-07 | 1.7E-05 | 2.8E-05 |
| | *h* | 1.6E-06 | 5.1E-07 | 3.4E-04 | 1.1E-04 |
| Chok 05 ii) | *Noload* | -2.2E-06 | 1.6E-06 | -3.5E-04 | 2.5E-04 |
| | *50%inc.* | -2.3E-06 | 1.2E-06 | -7.5E-04 | 3.9E-04 |
| | *100%* | -1.2E-06 | 2.2E-06 | -2.0E-04 | 3.4E-04 |
| | *50%dec.* | -1.6E-06 | 1.2E-06 | -5.2E-04 | 3.7E-04 |
| | *f0* | 2.6E-07 | 2.7E-07 | 4.1E-05 | 4.2E-05 |
| | *h* | -1.3E-07 | 3.0E-07 | -4.2E-05 | 9.5E-05 |
| DmTN ii) | *Noload* | 4.9E-07 | 3.5E-07 | -6.1E-05 | 4.4E-05 |
| | *50%inc.* | -8.0E-07 | 1.0E-07 | 2.0E-04 | 2.6E-05 |
| | *100%* | -2.4E-06 | 2.3E-07 | 3.0E-04 | 2.9E-05 |
| | *50%dec.* | -1.9E-06 | 1.5E-07 | 4.8E-04 | 3.8E-05 |
| | *f0* | -2.8E-08 | 6.8E-08 | 3.5E-06 | 8.5E-06 |
| | *h* | -1.2E-06 | 1.5E-07 | 3.9E-01 | 4.9E-02 |
| TT1 i) | *Noload* | -3.6E-06 | 4.0E-07 | -3.4E-04 | 3.8E-05 |
| | *50%inc.* | 4.3E-06 | 1.3E-06 | 8.1E-04 | 2.5E-04 |
| | *100%* | 2.1E-06 | 1.3E-06 | 1.9E-04 | 1.2E-04 |
| | *50%dec.* | 6.5E-07 | 7.8E-07 | 1.2E-04 | 1.5E-04 |
| | *f0* | -2.3E-07 | 8.0E-08 | -2.1E-05 | 7.4E-06 |
| | *h* | -3.7E-06 | 8.7E-07 | -6.2E+00 | 1.5E+00 |
| TB2 i) | *Noload* | 1.2E-07 | 1.0E-07 | 2.3E-05 | 2.0E-05 |
| | *100%* | -1.3E-06 | 1.7E-07 | -2.6E-04 | 3.5E-05 |
| | *f0* | -3.2E-08 | 3.7E-08 | -6.3E-06 | 7.3E-06 |

Note: The measurement results are obtained by using AC excitation amplifier with 2 types of frequency;

i) represent frequency is 225.05 Hz and

ii) represent frequency is 600 Hz

Fig. 8 shows humidity sensitivity of each torque measuring device group by classification of humidity protection of strain gauge as following;

- Group A, without protective covering
- Group B, protective covering on strain gauge
- Group C, waterproof protection
- Group D, hermetically sealed

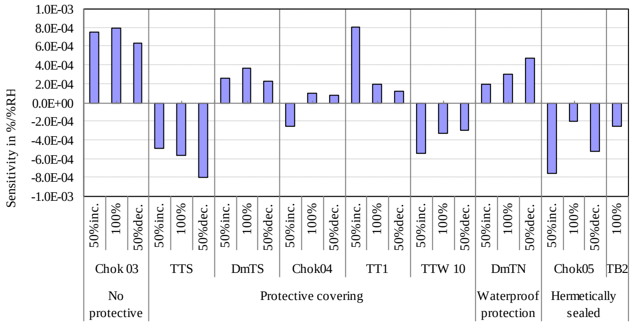



**Fig. 8,** Humidity stability of torque measuring devices classified by humidity protection.

From the experimental results, both relative and absolute humidity sensitivity has no correlation with applied torque. Thus humidity sensitivity value claimed should be derived from the experiment with at least 2-3 steps of torque applied.

Considering the sensitivity of each group, there is no relationship between sensitivity quantity and humidity protection quality. It shows that humidity protection is unable to reduce humidity effect as of its purpose. In other word, humidity absorption of strain gauge is not the main parameter affecting the sensitivity.

To substantiate a hypothesis that an impedance of bridge strain gauge circuit for alternating current supply voltage is the cause of stability due to humidity, some of torque transducer was measured to study on humidity sensitivity by using DC excitation amplifier. The measurement results as shown in Table 3. The objective is to provide measurement results obtained from a bridge strain gauge circuit with only resistance and compare them with the experiment results obtained from a bridge strain gauge circuit with elements of impedance.

The results show that the stability of the DC excitation amplifier is significantly less affected by humidity than using AC excitation amplifier as shown in Fig. 9-13, graph of measurement comparison results between DC excitation amplifier and AC excitation amplifier. Therefore, it is concluded that the humidity stability does not mainly come from moisture absorption of stain gauge directly but mainly comes from electrical properties of the bridge strain gauge circuit, especially the impedance.

**Table 3:** The humidity sensitivity obtained by using DC excitation amplifier.

| Torque Measuring Devices | Parameter | Humidity effect | | | |
|---|---|---|---|---|---|
| | | (mV/V)/%RH | | %/%RH | |
| | | Sensitivity | SD. | Sensitivity | SD. |
| TTW10 | *Noload* | -1.9E-05 | 1.5E-06 | -2.8E-03 | 2.3E-04 |
| | *50%inc.* | -1.2E-06 | 9.5E-07 | -3.7E-04 | 2.9E-04 |
| | *100%* | -2.9E-06 | 1.2E-06 | -4.4E-04 | 1.8E-04 |
| | *50%dec.* | -1.3E-06 | 1.2E-06 | -3.8E-04 | 3.6E-04 |
| | *f0* | -1.9E-05 | 1.5E-06 | -2.8E-03 | 2.3E-04 |
| | *h* | 6.5E-07 | 4.5E-07 | 5.4E-01 | 3.7E-01 |
| Chok 03 | *Noload* | 1.3E-04 | 5.4E-06 | 9.7E-03 | 4.0E-04 |
| | *50%inc.* | -2.7E-07 | 1.1E-06 | -4.0E-05 | 1.6E-04 |
| | *100%* | 1.3E-06 | 1.7E-06 | 9.4E-05 | 1.3E-04 |
| | *50%dec.* | 1.2E-06 | 1.4E-06 | 1.7E-04 | 2.1E-04 |
| | *f0* | -8.2E-08 | 3.0E-07 | -6.0E-06 | 2.2E-05 |
| | *h* | 1.5E-06 | 1.8E-06 | 4.9E-01 | 6.1E-01 |
| DmTN | *Noload* | -1.6E-07 | 2.8E-06 | 2.1E-05 | 3.6E-04 |
| | *50%inc.* | -2.4E-07 | 1.6E-07 | 6.2E-05 | 4.0E-05 |
| | *100%* | -4.9E-07 | 5.9E-07 | 6.2E-05 | 7.5E-05 |
| | *50%dec.* | -4.5E-07 | 5.9E-07 | 1.2E-04 | 1.5E-04 |
| | *f0* | 5.6E-08 | 8.6E-08 | -7.1E-06 | 1.1E-05 |
| | *h* | -2.4E-07 | 4.5E-07 | 9.1E-02 | 1.7E-01 |
| TT1 | *Noload* | -5.0E-06 | 3.2E-07 | -4.6E-04 | 2.9E-05 |
| | *50%inc.* | 3.4E-07 | 1.1E-06 | 6.3E-05 | 2.0E-04 |
| | *100%* | -1.1E-06 | 1.5E-06 | -1.0E-04 | 1.4E-04 |
| | *50%dec.* | 2.8E-07 | 1.2E-06 | 5.3E-05 | 2.2E-04 |
| | *f0* | 1.9E-07 | 2.4E-07 | 1.8E-05 | 2.2E-05 |
| | *h* | -9.0E-08 | 9.2E-07 | -1.7E-05 | 1.7E-04 |
| TB2 | *Noload* | 8.4E-08 | 1.6E-07 | 1.7E-05 | 3.2E-05 |
| | *100%* | -1.0E-06 | 6.5E-07 | -2.0E-04 | 1.3E-04 |
| | *f0* | -1.7E-08 | 1.2E-07 | -3.4E-06 | 2.4E-05 |

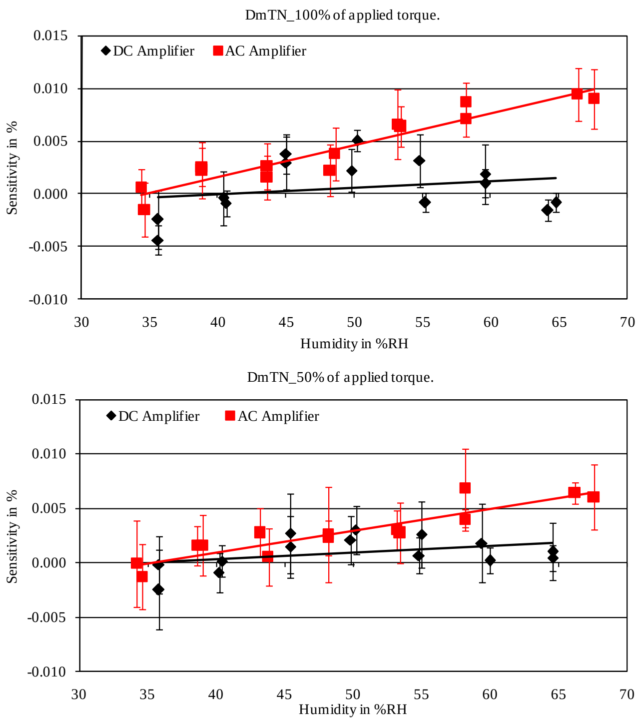



**Fig. 9,** The comparison results of torque measuring devices model DmTN.

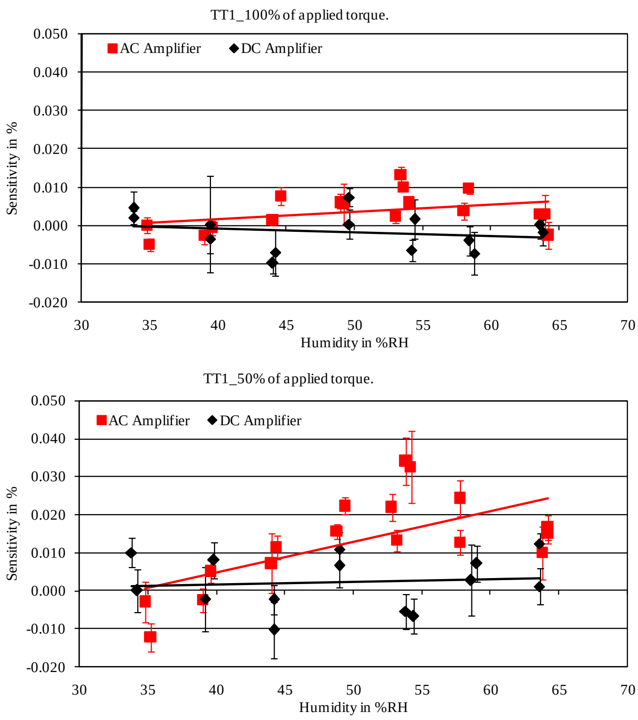



**Fig. 10,** The comparison results of torque measuring devices model TT1.

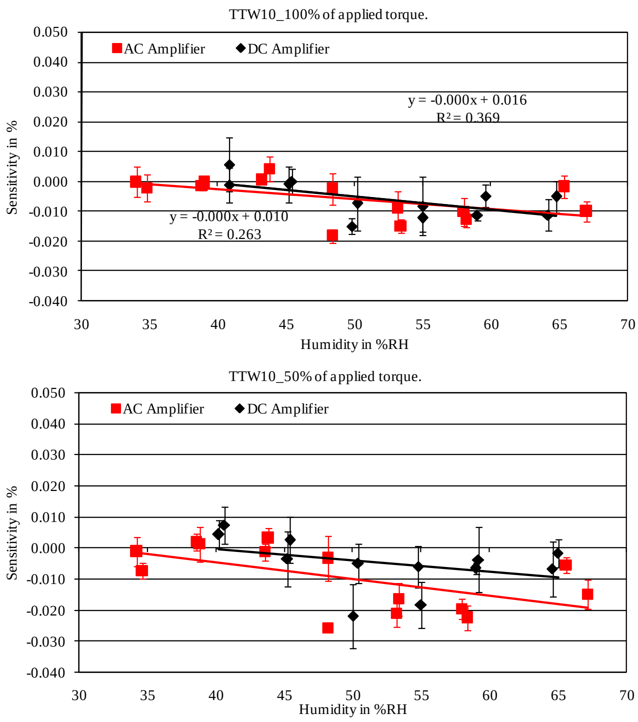



**Fig. 11,** The comparison results of torque measuring devices model TTW10.

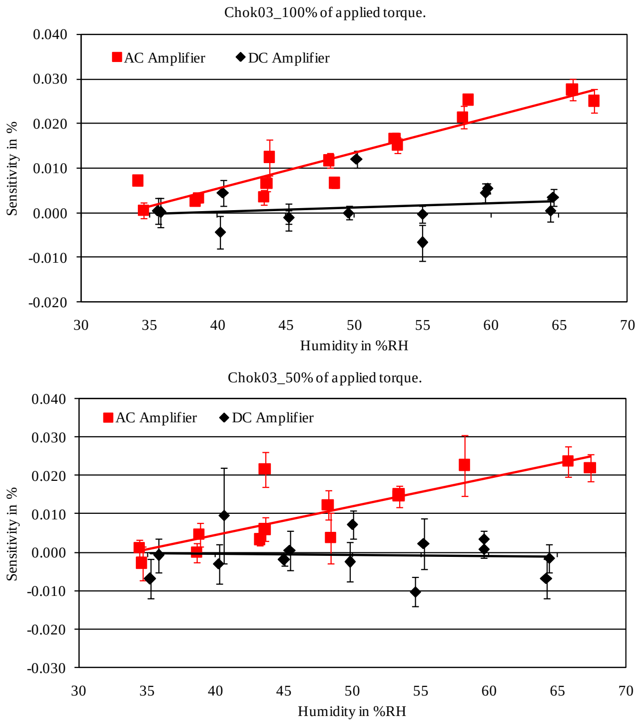



**Fig. 12,** The comparison results of torque measuring devices model Chok 03.

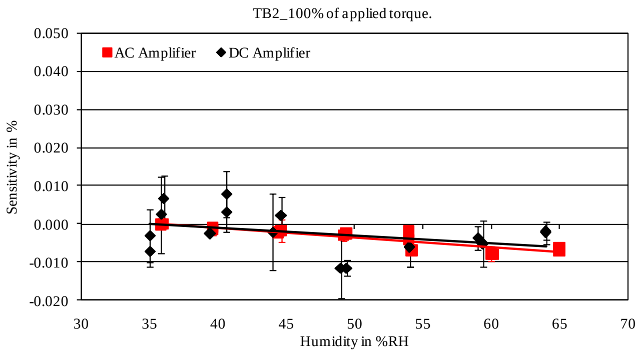



**Fig. 13,** The comparison results of torque measuring devices model TB2.

In order to clearer understand the effect of AC excitation with humidity sensitivity, thus the sensitivity comparison of two different types of excitation amplifier is shown in Fig. 14.

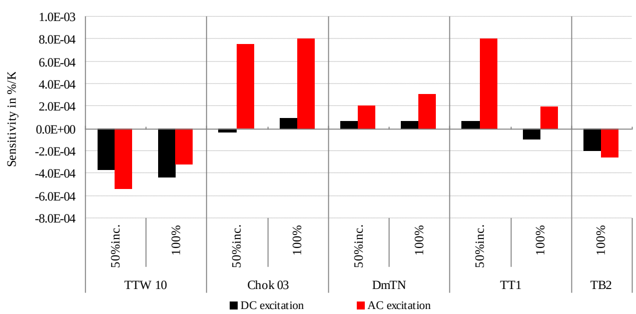



**Fig. 14,** The humidity sensitivity from 2 different types of excitation amplifier.

## 8. CONCLUSION

Major influence on the temperature sensitivity is temperature coefficient on gauge factor of strain gauge and Young's modulus of sensing body material. Although the temperature compensation circuit can reduce this impact approximately 10 times but the result is still not proper to be used in the secondary standard or inter laboratory comparison activities. Thus the study to find the effect of temperature must be done.

For torque measuring devices, degree of humidity protection has insignificant impact in reducing of humidity sensitivity while an electrical impedance property is the main factor affecting to sensitivity.

The conditions of bridge strain gauge circuit with only resistance or bridge strain gauge circuit with direct current excitation are the best condition in reducing sensitivity. Impedance quantity is varied according to frequency of alternating current power supply. This results change in of humidity sensitivity, as it is a result from frequency changing. Nowadays there are various amplifier frequencies so the impact of diverse frequency to humidity sensitivity should be studied.

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## 10. REFERENCE

[1] N. Arksonnarong, T. Sanponpute, "A Study of Torque Transfer Wrench Stability", The 3rd TSME International Conference on Mechanical Engineering, Chiang Rai, October 2012.

[2] T. Sanponpute, C. Watthong, "PROTOTYPE OF LOAD CELL APPLICATION IN TORQE MEASUREMENT", IMEKO 2010 TC3, TC5 and TC22 Conferences Metrology in Modern Context, November 22-25, 2010.

[3] T. Sanponpute, C. Wattong, N. Arksornarong, "A Design on Hermetically Sealed Torque Transfer Wrench", The Asia-Pacific Symposium on Measurement of Mass, Force, Torque, Xi'an, 2011.

[4] William H. Hayt, Jr.,"ENGINEERING ELECTROMAGNETICS", McGRAW-HILL INTERNATIONAL EDITIONS, ISBN 0071004882. 5th edition

[5] Final Report on the Torque Key Comparison CCM.T-K1, BIPM key comparison database, Appendix C, URL:http://kcdb.bipm.org/appendixb/appbresults/ccm.t-k1/ccm.t-k1_final_report.pdf, access on 24/02/2011

[6] DAkkS-DKD–R 3-7, "Guideline of static calibration of reference torque wrenches", Edition 1/2010.

[7] DIN 51309, "Guideline of material testing machines calibration of static torque measuring devices", Edition 2005.