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INTER-LABORATORIES COMPARISON OF REFERENCE TORQUE WRENCH CALIBRATION BETWEEN NMIJ AND PTB

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Abstract: Inter-laboratories comparison of reference torque wrench calibration was conducted between the NMIJ and the PTB using a torque transducer with the form of torque wrench, TTS/100Nm, the rated capacity of which was 100 N·m, as a transfer device. Under various calibration conditions, the calibration results obtained by both laboratories were coincided within the range of uncertainties of measurement.

Keywords: reference torque wrench, inter-comparison, square drive.

1. INTRODUCTION

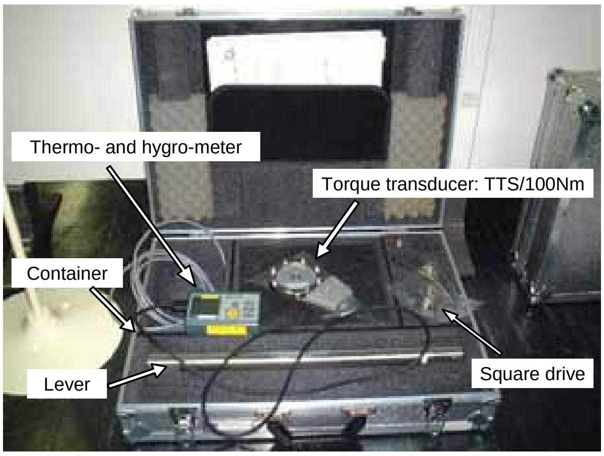
A reference torque wrench (RTW) is one of the key technologies for the establishment of an SI traceability system in torque metrology. General hand torque wrenches are usually calibrated or tested using torque wrench testers (TWTs, or torque wrench calibration devices (TWCDs)). TWTs are calibrated using RTWs. The SI traceability of torque can be completed by calibrating RTWs at accredited calibration laboratories or national metrology institutes (NMIs).

The RTW is defined as the complete set of a torque transducer with the form of torque wrench, a cable and an amplifier/indicator.[1] The number of laboratories providing the calibration of RTWs remains quite small yet. Physikalisch-Technische Bundesanstalt (PTB) has had a lot of experience in the calibration of RTWs over the last decade [1, 2]. National Metrology Institute of Japan (NMIJ) has also provided an RTW calibration service since early 2004. Unfortunately, however, there exists neither standard documentation nor mutually agreed international guidelines for the method of calibrating RTWs. Thus, the authors compared the calibration results for an RTW obtained by the NMIJ and the PTB under their respective procedures in order to confirm the equivalence of RTW calibration capability at these institutes.

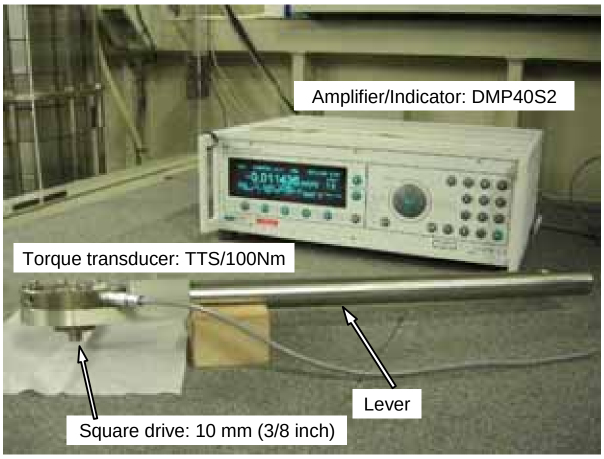
2. EXPERIMENTAL CONDITIONS

2.1. Equipment

A torque transducer with a rated capacity of 100 N·m (TTS/100Nm) was transferred by hand (transported in an airplane cabin) from the NMIJ to the PTB and vice versa, so that the surrounding environment of the transducer during transportation has not adversely affected it. Figure 1(a) shows the TTS/100Nm and its container, along with a thermo- and hygro-meter and a dehumidifying agent (total



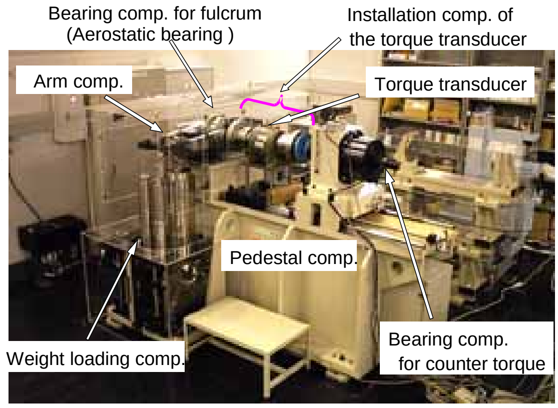
(a) Transfer devices



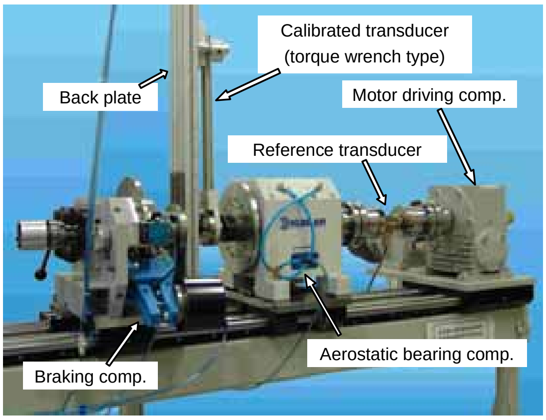
(b) Complete assembly of RTW

Fig. 1. Reference torque wrench

[1] In Japan, the term "reference torque wrench" has been stated in the Measurement Law, whereas it has been revised to "Transfer torque wrench" in DKD-R 3-7:2003 in Germany.



(a) 1 kN·m-DWTSM at the NMIJ



(b) 2-kN·m-Dm-KE at the PTB

Fig. 2. Torque calibration equipment at each NMI

weight: 9.5 kg). The temperature ranged from 18 to 27 °C and the relative humidity ranged from 15 to 20 %RH during transportation.

Identical amplifier/indicators (DMP40S2) from each laboratory were connected to the TTS/100Nm and were used for the measurement during each calibration. Here, the difference in voltage ratio span of the two DMP40S2s and short term drift of them were assumed to be efficiently smaller than the total uncertainty of the RTW calibration and so were not considered. Figure 1(b) shows the complete assembly of RTW (TTS/100Nm and DMP40S2).

A deadweight type torque standard machine with a rated capacity of 1 kN·m (1 kN·m-DWTSM) was used for the sssss

Table 1 Comparison schedule

Event	Lab.	Date
Pre-calibration	NMIJ	June 3rd, 2004
Transportation	-----	June 6th, 2004
On-site calibration	PTB	June 9th, 2004
Transportation	-----	June 27th, 2004
Post-calibration	NMIJ	June 30th, 2004

calibration at the NMIJ. The Calibration and Measurement Capability (CMC) for the RTW calibration has been declared to be less than 7.0 · 10^{-5} of relative expanded uncertainty (k = 2) in the range from 5 N·m to 1 kN·m. A comparison type (or reference type) torque calibration machine with a rated capacity of 2 kN·m (2-kN·m-Dm-KE) was used for the calibration at the PTB. The CMC for all kinds of calibration has been declared to be less than 2.0 · 10^{-4} of the relative expanded uncertainty (k = 2) in the range from 1 N·m to 2 kN·m. The 1 kN·m-DWTSM and 2-kN·m-Dm-KE are shown in Fig.2.

2.2. Calibration procedure

The comparison schedule is shown in Table 1. After pre-calibration at the NMIJ, the TTS/100Nm was transferred from NMIJ to PTB and vice versa.

2.2.1. Calibration at the NMIJ

In the pre- and post-calibrations at the NMIJ, the torque transducer was mounted on the 1 kN·m-DWTSM as shown in Fig. 3. The square drive of the torque transducer on the measuring side was fixed to a special square hole adapter (as shown in Fig. 4). The loading point on the lever of the RTW was supported in the circumferential direction with a back plate fixed to the bearing component for the counter torque of the 1 kN·m-DWTSM. Diaphragm (elastic) couplings were not used for the calibration of the RTW in order to support the torque transducer vertically as much as possible on the measurement axis.

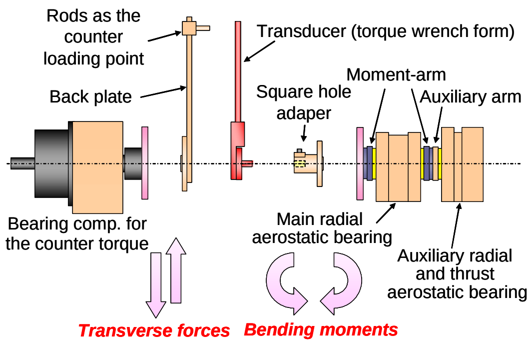


Fig. 3. Mounting method of the transducer of RTW on the 1 kN·m-DWTSM

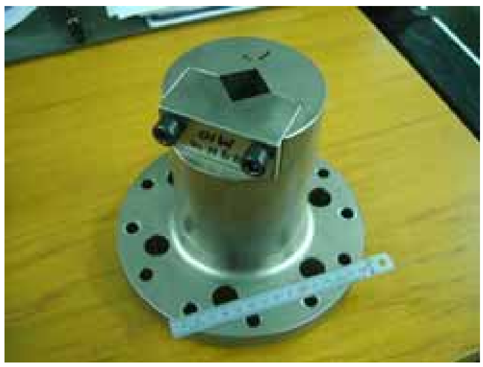


Fig. 4. Square hole adapter flange

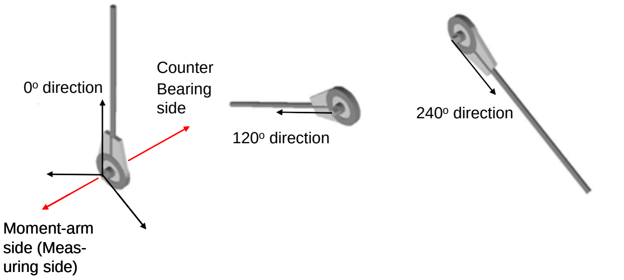
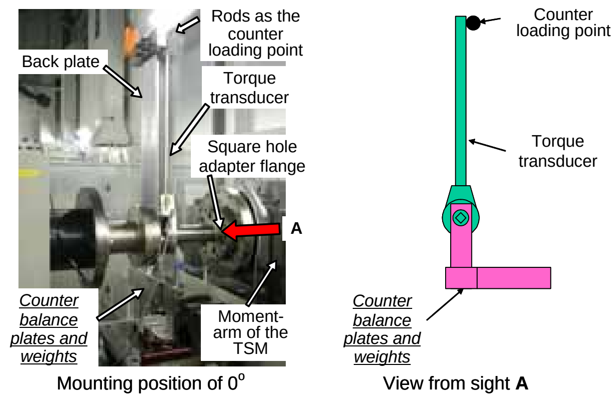
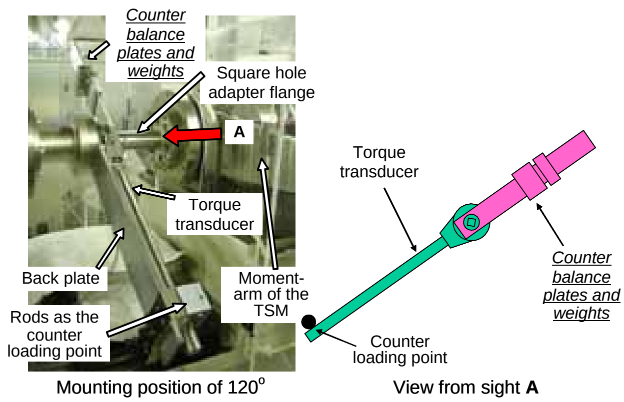


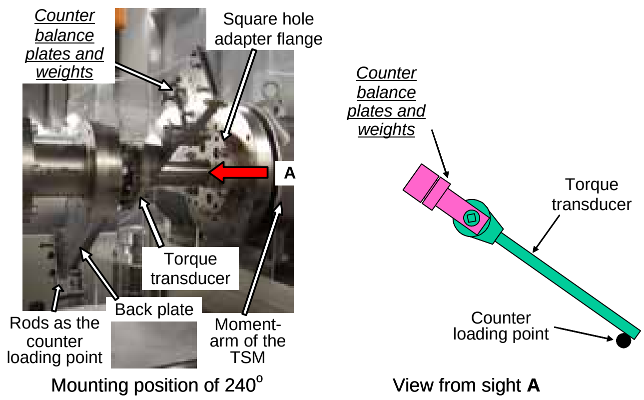
Fig. 5. Rotational mounting position of the transducer at the NMIJ



(a) Mounting position of 0°



(b) Mounting position of 120°



(c) Mounting position of 240°

Fig. 6. Mounting method by changing the lever direction

First, two measurement cycles of increasing and decreasing torque were made after preloading the RTW three times in the rotational mounting position of 0°. Eight torque steps of 10, 20, 30, 40, 50, 60, 80 and 100 % of the rated capacity of the RTW basically constitute the measurement cycle. One measurement cycle of increasing and decreasing torque was performed after preloading the RTW once after changing the rotational position to 120° and 240°, respectively, as shown in Fig.5.

In order to attain zero balance, an initial torque of 1 to 2 % of the maximum torque of the RTW was loaded by placing weights on the end of the moment-arm. Moreover, counterbalance plates and weights were attached to the RTW on the opposite side of the lever to generate an additional small constant torque of 1 to 2 % in any mounting position. The mounting method of the transducer on the 1 kN·m-DWTSM at each position is shown in Fig. 6. These techniques are important for the calibration of RTWs when using deadweight type and horizontal measurement axis type torque standard machines[3].

The calibration sequence was performed according to the defined timetable in order to minimize the influence of the creep characteristic of the RTW. Each datum should be recorded once, 30 seconds after each torque step has been achieved.

After measurement at 240°, one measurement cycle of increasing and decreasing torque was performed changing the lever length of the RTW from the averaged lever length (500 mm) to the minimum lever length (300 mm) by moving the rods as the counter loading point.

Calibration was conducted separately for the clockwise (CW) and counterclockwise (CCW) directions.

2.2.2. Calibration at the PTB

In the on-site calibration at the PTB, the torque transducer was mounted on the 2-kN·m-Dm-KE, as shown in Fig. 7. Calibration at the PTB was essentially similar to the pre- and post-calibrations at the NMIJ, except for the following conditions:

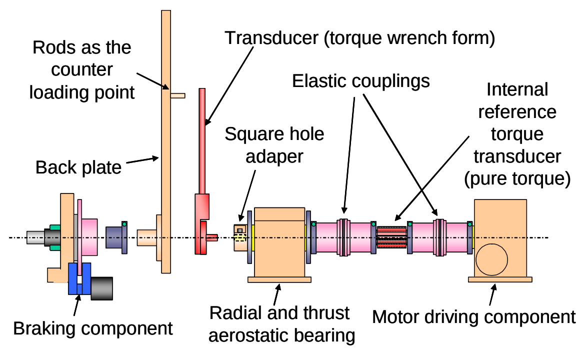


Fig. 7. Mounting method of the transducer of RTW on the 2-kN·m-Dm-KE

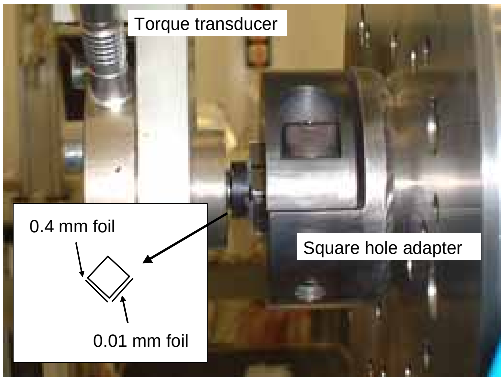


Fig. 8. Center adjusting by using thin metal foils

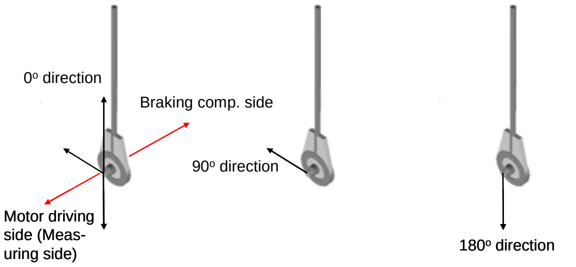


Fig. 9. Rotational mounting position of the transducer at PTB

(1) In this TTS/100Nm, a 10-mm (3/8-inch) detachable square drive is normally used, however a 12.5-mm (1/2-inch) square drive was used for the on-site calibration because there were no 10-mm (3/8-inch) square hole adapters available at the PTB.

(2) The center alignment of the square drive was adjusted by inserting thin metal foil between the square drive and square hole adapter as shown in Fig.8. The eccentricity was reduced to less than 0.05 mm.

(3) The rotational mounting position was changed by maintaining the lever of the transducer in the vertical direction and changing the direction of the detachable square drive from the body of the transducer by pitches of 0, 90 and 180°, as shown in Fig.9. In this case, counterbalance plates and weights were not required.

3. RESULTS AND DISCUSSION

3.1. *Short-term drift*

The short-term drift of the TTS/100Nm (difference between pre- and post-calibration results) is shown in Fig.10. The short-term drift of approximately one month was within 0.02 % for increasing torque and was within 0.04 % for decreasing torque. Generally, the reproducibility of re-mounting of the transducer affects the short-term drift of the RTW much more than the sensitivity drift of the transducer itself. It was found that the reproducibility of re-mounting of the transducer between pre- and post-calibrations at the NMIJ was sufficiently small. The reason for the comparatively large deviation of the decreasing torque in the CCW remains unclear.

3.2. *Comparison of calibration results*

The relative deviation of the on-site calibration at the PTB compared with the mean values of pre- and post-calibration at the NMIJ is shown in Fig. 11. The relative deviations were all within 0.01 % except for a 10 % step in decreasing torque. Calibration values and relative expanded uncertainties (k = 2) are summarized in Table 2, where the uncertainties were evaluated according to the guideline JMIF-016[4], and the contributions of the hysteresis and zero-error are not included. The equivalence of the calibration for RTWs was proven between the NMIJ and PTB.

The mounting position can be easily changed by changing the detachable square drive and this method is likely to be acceptable for use in the private calibration laboratories. The uncertainty of calibration, however, becomes larger than the results obtained by changing the lever direction itself. On the other hand, the method of changing the lever direction is not easy and requires significant time and skill.

4. CONCLUSION

The calibration results of the same RTWs (the identical TTS/100Nm and each DMP40S2) obtained by the NMIJ and the PTB were compared. The relative deviations were all within 0.01 % except for a 10 % step in decreasing torque. Equivalence of calibration for RTWs between the NMIJ and the PTB was proven.

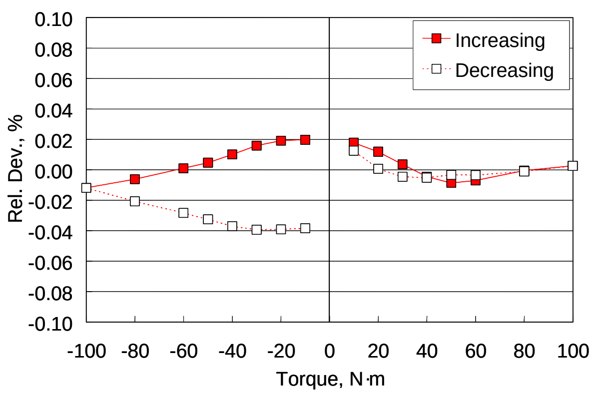


Fig. 10. Short-term drift of the TTS/100Nm

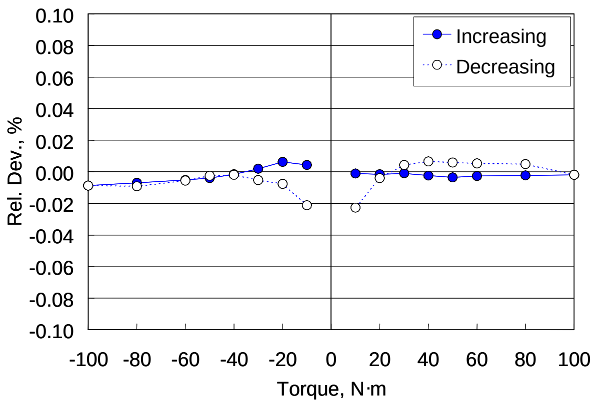


Fig. 11. Comparison results (relative deviations)

Table 2 Calibration values and relative expanded uncertainties *U* (*k* =2)

Clockwise						
Torque in N·m	Pre-calibration at the NMIJ		On-Site calibration at the PTB		Post-calibration at the NMIJ	
	Value in mV/V	*U* in %	Value in mV/V	*U* in %	Value in mV/V	*U* in %
10	0.185929	0.048	0.185943	0.056	0.185962	0.024
20	0.371859	0.033	0.371875	0.050	0.371903	0.015
30	0.557787	0.026	0.557791	0.045	0.557807	0.019
40	0.743720	0.021	0.743686	0.042	0.743687	0.021
50	0.929638	0.017	0.929564	0.040	0.929557	0.019
60	1.115499	0.016	1.115430	0.038	1.115421	0.019
80	1.487176	0.010	1.487139	0.036	1.487169	0.015
100	1.858803	0.011	1.858792	0.035	1.858852	0.015
80	1.486944	-----	1.487009	-----	1.486929	-----
60	1.115170	-----	1.115211	-----	1.115132	-----
50	0.929293	-----	0.929333	-----	0.929263	-----
40	0.743438	-----	0.743468	-----	0.743400	-----
30	0.557574	-----	0.557585	-----	0.557548	-----
20	0.371712	-----	0.371698	-----	0.371714	-----
10	0.185839	-----	0.185809	-----	0.185863	-----

Counterclockwise						
Torque in N·m	Pre-calibration at the NMIJ		On-Site calibration at the PTB		Post-calibration at the NMIJ	
	Value in mV/V	*U* in %	Value in mV/V	*U* in %	Value in mV/V	*U* in %
-10	-0.185943	0.008	-0.185970	0.035	-0.185980	0.032
-20	-0.371890	0.008	-0.371949	0.024	-0.371961	0.024
-30	-0.557851	0.007	-0.557907	0.025	-0.557940	0.019
-40	-0.743823	0.007	-0.743850	0.026	-0.743898	0.015
-50	-0.929793	0.007	-0.929778	0.025	-0.929837	0.012
-60	-1.115747	0.007	-1.115695	0.024	-1.115760	0.010
-80	-1.487673	0.007	-1.487524	0.023	-1.487582	0.009
-100	-1.859583	0.007	-1.859309	0.021	-1.859362	0.009
-80	-1.487738	-----	-1.487449	-----	-1.487431	-----
-60	-1.115823	-----	-1.115603	-----	-1.115507	-----
-50	-0.929853	-----	-0.929679	-----	-0.929551	-----
-40	-0.743880	-----	-0.743728	-----	-0.743604	-----
-30	-0.557897	-----	-0.557759	-----	-0.557678	-----
-20	-0.371914	-----	-0.371813	-----	-0.371769	-----
-10	-0.185937	-----	-0.185862	-----	-0.185866	-----

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