INTERNAL COMPARISON BETWEEN A REFERENCE TYPE TORQUE CALIBRATION MACHINE AND A 10 N·m DEADWEIGHT TORQUE STANDARD MACHINE

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Abstract:
A reference torque calibration machine (RTCM) has been developed to validate the calibration of efficient torque transducers. In this study, the calibration and measurement capability (CMC) of the RTCM was evaluated based on the technical guideline. We also compared the RTCM and a 10 N·m deadweight torque standard machine at the National Metrology Institute of Japan (NMIJ) using a torque measuring device with a nominal capacity of 1 N·m.

Keywords: torque; calibration; reference type torque calibration machine; internal comparison; uncertainty

1. INTRODUCTION

A reference torque calibration machine (RTCM) has been developed to improve the efficiency of calibration service for torque measuring devices at the National Metrology Institute of Japan (NMIJ), part of the National Institute of Advanced Industrial Science and Technology (AIST) [1]. The nominal capacity of the RTCM is 10 N·m. In this study, we evaluated the calibration and measurement capability (CMC) of the RTCM. Then, the RTCM was compared with a deadweight torque standard machine with a nominal capacity of 10 N·m (10-N·m-DWTSM) by using a small-rated-capacity torque measuring device.

2. A REFERENCE TORQUE CALIBRATION MACHINE AND REFERENCE TORQUE TRANSDUCERS

Figure 1 shows a photograph of the RTCM under development at NMIJ. This machine consists of a motor, a reduction gear, couplings, a reference torque transducer, an aerostatic bearing, *z*-axis sliders, and frames. Figure 2 shows a screenshot of the RTCM measurement control program. This program was written in LabVIEW from National Instruments. This program can perform all of the loading timetable settings, motor control, and measurement. Figure 3 shows a photograph of reference torque transducers. Reference torque transducers are the DmTN/1Nm with a nominal capacity of 1 N·m and the DmTN/10Nm with a nominal capacity of 10 N·m from GTM GmbH, respectively. The indicator/amplifier is the DMP40S2 from HBM GmbH. They are calibrated by using the 10-N·m-DWTSM at NMIJ.

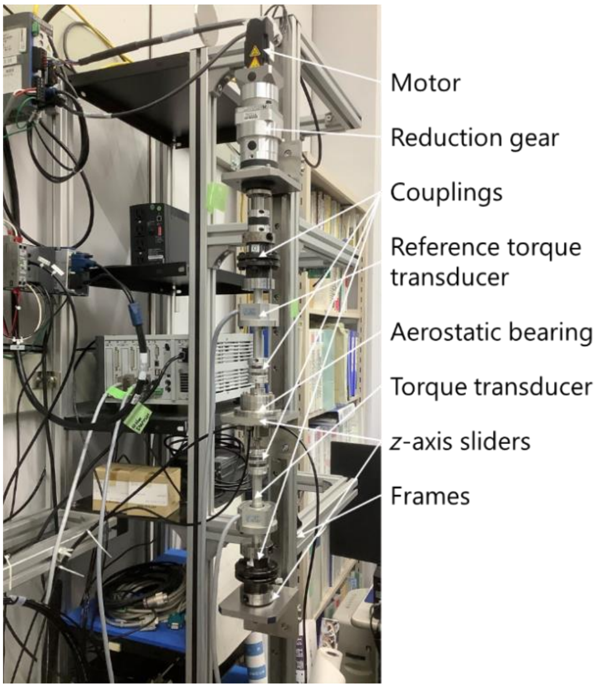

Figure 1: A reference torque calibration machine with a nominal capacity of 10 N·m

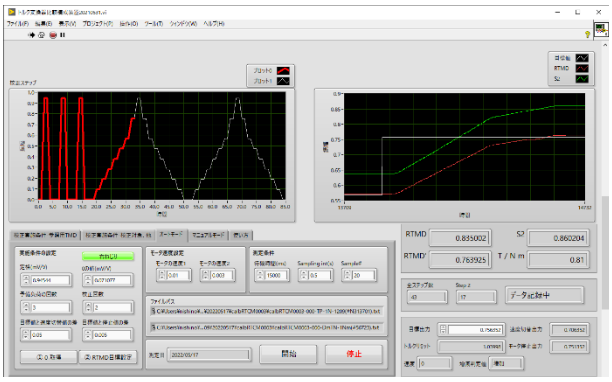

Figure 2: A measurement control program for the RTCM

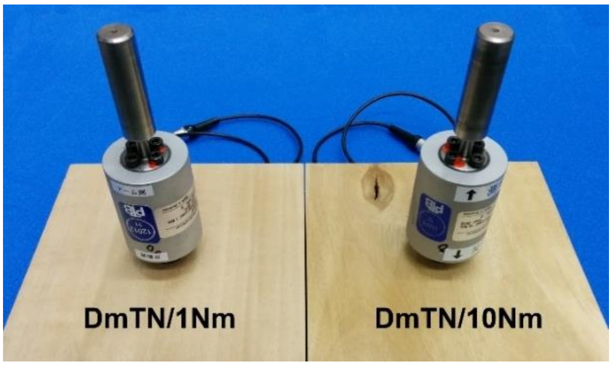

Figure 3: Reference torque transducers with nominal capacities of 1 N·m and 10 N·m

3. EVALUATION OF THE CMC OF RTCM

The CMC of RTCM was evaluated in accordance with the JCG209S12 technical guideline [2]. As a result, CMCs were evaluated to be 0.02 % and 0.04 % in the range of 1 N·m to 10 N·m and 0.1 N·m to 1 N·m, respectively. In particular, the uncertainties based on the long-term stability of the reference torque measuring devices, $w_{\mathrm{trq.lgstb}}$, was evaluated based on the calibration results of the past eight years. As a result, $w_{\mathrm{trq.lgstb}}$ for DmTN/1Nm and DmTN/10Nm were 0.009 6 % and 0.002 7 %, respectively.

4. EXPERIMENTAL CONDITIONS

4.1. A 10 N·m Deadweight Torque Standard Machine

Figure 4 shows a photograph of the 10-N·m-DWTSM at NMIJ. The basic hardware components of the 10-N·m-DWTSM are moment arms, weight loading components, a counter bearing drive, installation components for a torque transducer, a pedestal, and a windshield. The CMC of the 10-N·m-DWTSM is evaluated to be 0.007 0 % in the range from 0.1 N·m to 10 N·m.

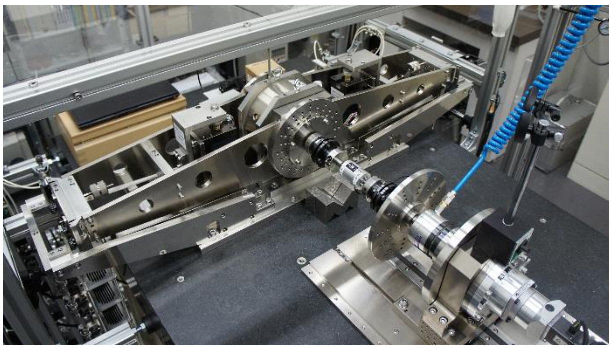

Figure 4: The 10 N·m deadweight torque standard machine at NMIJ

4.2. Transfer Device

Figure 5 shows a photograph of a transfer device used in the internal comparison. A torque transducer was TP-1N-0302 with a nominal capacity of 1 N·m from Showa Measuring Instruments Co., Ltd [3]. The indicator/amplifier was MGCplus ML38B from HBM GmbH.

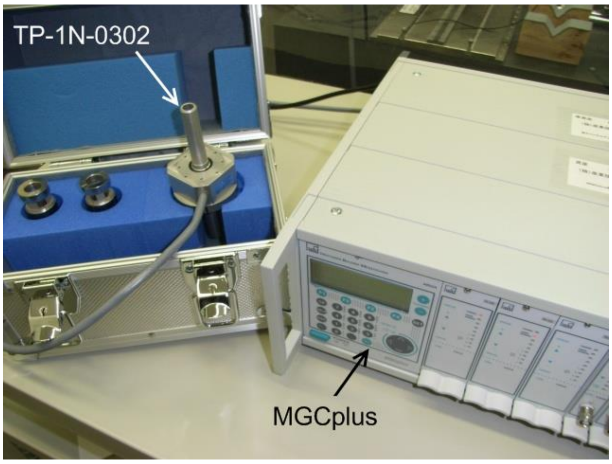

Figure 5: Photograph of a transfer device

4.3. Calibration Procedure

A calibration procedure in the internal comparison was based on the JMIF-015 technical guidelines [4]. Figure 6 and Figure 7 show the loading timetables and setting direction of the torque transducer for measuring axis. Eight torque steps (0.1 N·m, 0.2 N·m, 0.3 N·m, 0.4 N·m, 0.5 N·m, 0.6 N·m, 0.8 N·m and 1.0 N·m) were selected. The TP-1N-0302 was measured separately in the clockwise (CW) and the counter clockwise (CCW) directions, and it was rotated from 0° to 240° in 120° steps for the angular position relative to the reference torque transducer.

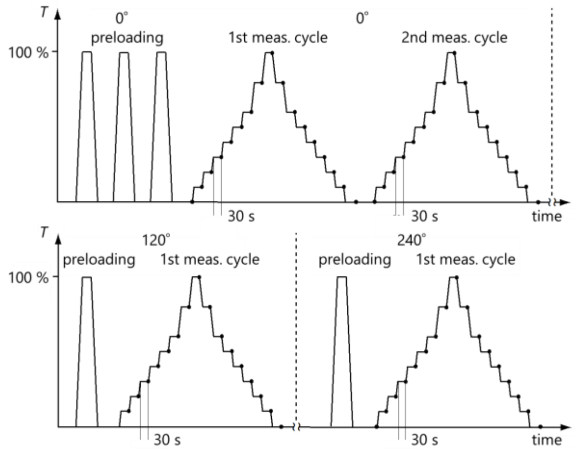

Figure 6: Loading timetable based on the JMIF-015:2004-8 technical guideline

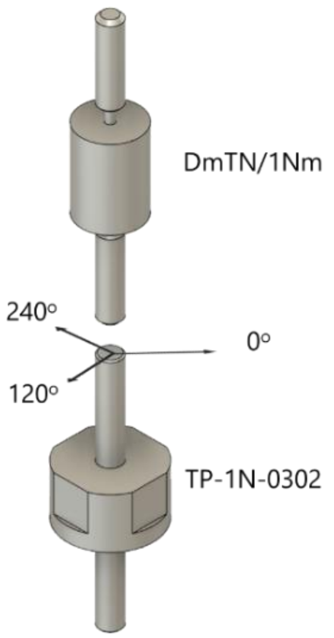

Figure 7: Changing the mounting position for the transfer device

5. RESULT AND DISCUSSION

Table 1 shows the comparison results between the RTCM and the 10-N·m-DWTSM. S_{TSM} and S_{RTCM} are measurement results for the 10-Nm-DWTSM and the RTCM, respectively. RD is the relative deviation expressed by equation (1).

$$RD = \frac{S_{\mathrm{RTCM}} - S_{\mathrm{TSM}}}{|S_{\mathrm{TSM}}|} \quad (1)$$

W_{TSM} and W_{RTCM} are the uncertainty of measurement results by the 10-N·m-DWTSM, and the uncertainty of measurement results by the RTCM, respectively.

Table 1: Comparison results between the RTCM and the 10-N·m-DWTSM

Direction	Torque / N·m	S_{TSM} / (mV/V)	S_{RTCM} / (mV/V)	RD / %	W_{TSM} (k = 2) / %	W_{RTCM} (k = 2) / %	E_{n}
CCW	-0.1	-0.102 037	-0.102 063	-0.026 1	0.017	0.040	-0.06
	-0.2	-0.204 052	-0.204 072	-0.010 1	0.013	0.040	-0.05
	-0.3	-0.306 058	-0.306 112	-0.017 5	0.009 9	0.040	-0.13
	-0.4	-0.408 064	-0.408 111	-0.011 5	0.008 4	0.040	-0.11
	-0.5	-0.510 060	-0.510 120	-0.011 8	0.007 9	0.040	-0.15
	-0.6	-0.612 055	-0.612 120	-0.010 6	0.008 1	0.040	-0.16
	-0.8	-0.816 035	-0.816 111	-0.009 4	0.008 8	0.040	-0.19
	-1.0	-1.019 998	-1.020 092	-0.009 1	0.007 7	0.040	-0.23
	-0.8	-0.815 975	-0.816 032	-0.007 0	0.011	0.040	-0.14
	-0.6	-0.611 976	-0.612 012	-0.005 8	0.008 5	0.040	-0.09
	-0.5	-0.509 981	-0.510 027	-0.008 9	0.008 4	0.040	-0.11
	-0.4	-0.407 991	-0.408 004	-0.003 4	0.011	0.040	-0.03
	-0.3	-0.305 995	-0.305 982	0.004 0	0.017	0.040	0.03
	-0.2	-0.204 001	-0.203 957	0.021 5	0.028	0.047	0.08
	-0.1	-0.102 003	-0.101 946	0.055 9	0.046	0.060	0.08
CW	0.1	0.102 034	0.102 053	0.018 0	0.016	0.055	0.03
	0.2	0.204 049	0.204 041	-0.003 7	0.013	0.046	-0.02
	0.3	0.306 057	0.306 036	-0.006 9	0.011	0.040	-0.05
	0.4	0.408 059	0.408 015	-0.010 7	0.009 6	0.040	-0.11
	0.5	0.510 054	0.509 996	-0.011 3	0.009 1	0.040	-0.14
	0.6	0.612 046	0.611 973	-0.011 8	0.008 9	0.040	-0.18
	0.8	0.816 031	0.815 928	-0.012 6	0.008 9	0.040	-0.25
	1.0	1.019 991	1.019 869	-0.012 0	0.007 9	0.040	-0.30
	0.8	0.815 962	0.815 887	-0.009 2	0.013	0.040	-0.18
	0.6	0.611 963	0.611 932	-0.005 0	0.010	0.040	-0.07
	0.5	0.509 974	0.509 961	-0.002 5	0.009 5	0.040	-0.03
	0.4	0.407 980	0.407 992	0.003 0	0.012	0.040	0.03
	0.3	0.305 990	0.306 019	0.009 4	0.018	0.040	0.07
	0.2	0.203 996	0.204 036	0.019 2	0.031	0.040	0.08
	0.1	0.102 006	0.102 055	0.048 2	0.052	0.045	0.07

W_{TSM} and W_{RTCM} were evaluated in accordance with the JCG209S11 technical guideline [5]. Figure 8 shows the comparison results between the RTCM and the 10-N·m-DWTSM. E_{n} number [6] is given by equation (2).

$$E_{\mathrm{n}} = \frac{S_{\mathrm{RTCM}} - S_{\mathrm{TSM}}}{\sqrt{W_{\mathrm{RTCM}}^2 + W_{\mathrm{TSM}}^2}} \tag{2}$$

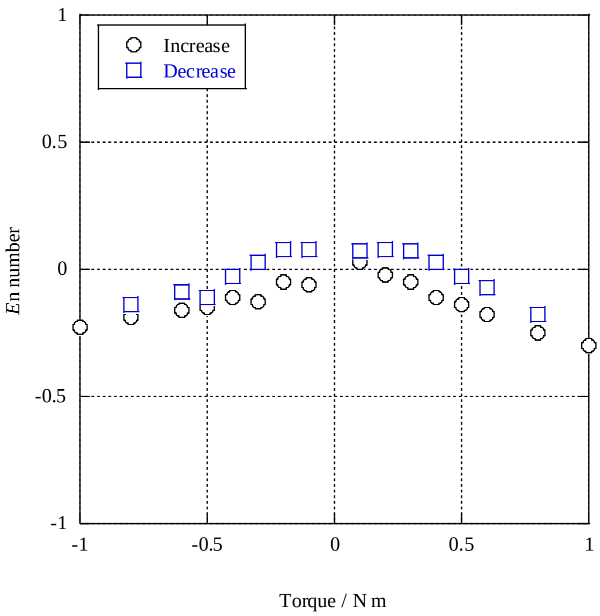

Figure 8: Comparison results between the RTCM and the 10-N·m-DWTSM using E_{n} number

In this figure, E_{n} numbers were within ±1 for all torque steps. Thus, the validity of the CMC evaluation of RTCM was confirmed in the range of 0.1 N·m to 1 N·m. In the future, we prepare a transfer device with a nominal capacity of 10 N·m and compare the 10-N·m-DWTSM and the RTCM by using it in the range of 1 N·m to 10 N·m. Moreover, we plan to investigate calibration methods for a reference torque wrench and a torque screwdriver tester using the RTCM.

6. SUMMARY

The RTCM at NMIJ has been developed to improve the efficiency of calibration service. In this study, the CMC of RTCM at NMIJ was evaluated in accordance with the JCG209S12 technical guideline [2]. CMCs of RTSM were evaluated to be 0.02 % and 0.04 % in the ranges of 1 N·m to 10 N·m and 0.1 N·m to 1 N·m, respectively. Then, the RTCM was compared with the 10-N·m-DWTSM at NMIJ by using the transfer device with a nominal capacity of 1 N·m. We evaluated the comparative results using E_{n} numbers. As a result, E_{n} numbers were within ±1 in the range of 0.1 N·m to 1 N·m. Thus, the validity of the CMC evaluation of RTCM was confirmed in this torque range.

7. REFERENCES

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