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CALIBRATION CHAIN FOR HAND TORQUE SCREWDRIVERS

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Abstract: Hand torque screwdrivers are used for the fastening control of screws in almost all precise mechanical and electrical parts. This paper describes the realization of a calibration chain for hand torque screwdrivers traceable to the national standard for torque. The calibration methods for a reference torque screwdriver using a primary torque standard machine, a torque screwdriver tester using the reference torque screwdriver, and hand torque screwdrivers using the torque screwdriver tester are also described.

Keywords: Torque, Standard, Screwdriver, Calibration.

1. INTRODUCTION

Hand torque screwdrivers (HTDs) are necessary for the assembly of medical, electrical, and precision devices in the production control process. There has been some progress in the development of calibration chains for hand torque wrenches (HTWs) in the last two decades [1–4]. However, the developmental progress of calibration chains for HTDs has been less reported.

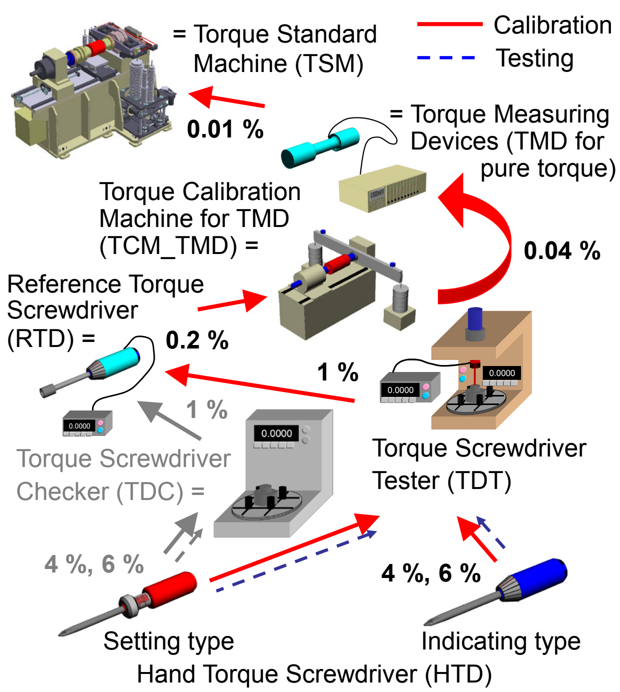

Fig. 1 Torque traceability system for HTDs proposed by NMIJ (percentages show the maximum permissible errors or approximate demanded uncertainty).

The authors have presented a comparison of the results for torque screwdriver testers (TDTs) by using a reference torque screwdriver (RTD) and a conventional weights and bar system (WBS) and have shown some of the advantages of a calibration chain including an RTD [5]. Parasitic transverse forces and bending moments necessarily occur superposing on pure torque during calibration using WBS. Figure 1 shows the calibration chain for HTDs with uncertainties (approximate) of calibrations and maximum permissible errors of tests for devices which are subject to.

This paper describes the establishment of a complete calibration chain from the national torque standard to HTDs, where the calibration and testing methods for the RTD using a national torque standard machine (TSM), for the TDT using the RTD, and for HTDs using the TDT are also investigated. It is shown that the traceability of the test results for HTDs is experimentally confirmed by this chain.

The torque range used for HTDs is generally small, e.g., from several centi-Newton meters to several Newton meters. National torque standards at such a small range have not been established in many countries, so the development of a calibration chain for HTDs has not progressed so much until recently. At the National Metrology Institute of Japan (NMIJ), a new deadweight torque standard machine (10-N·m-DWTSM) that is rated for 10 cN·m to 1000 cN·m has been completed and calibration service in this range has begun to the industry [6]. This development has accelerated the establishment of a calibration chain for HTDs.

One user in the medical field requested a digital HTD with the widest measuring range possible (for example, from 10 cN·m to 500 cN·m). The normative lower limit of an HTD is 20 % of its nominal torque value according to ISO 6789: 2003 [7]. This paper also focuses on the problem where the HTD is used in the special range beyond the lower limit of 20 % in conjunction with the limit of resolution in the reference device (TDT).

2. EXPERIMENTAL CONDITIONS

Experiments on the calibration chain were conducted as follows:

Experiment 1: Calibration of the RTD using the TSM as the reference standard.

Experiment 2: Calibration of the TDT using the RTD as the reference standard.

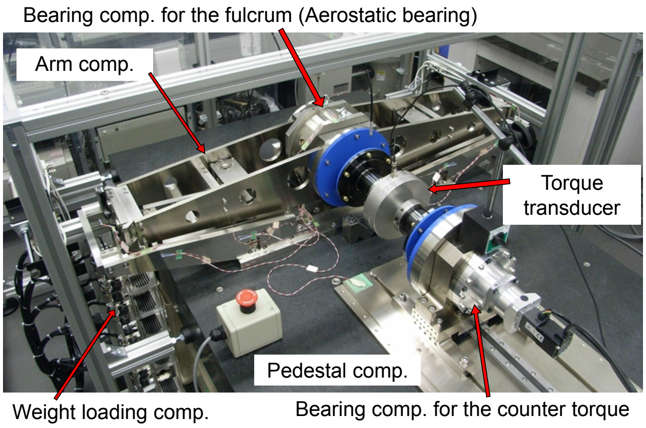

Fig. 2 Torque standard machine (10-N·m-DWTSM).

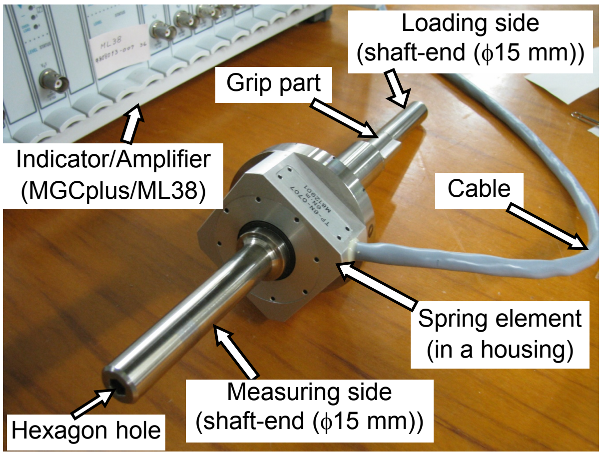

Fig. 3 Torque transducer with torque screwdriver shape.

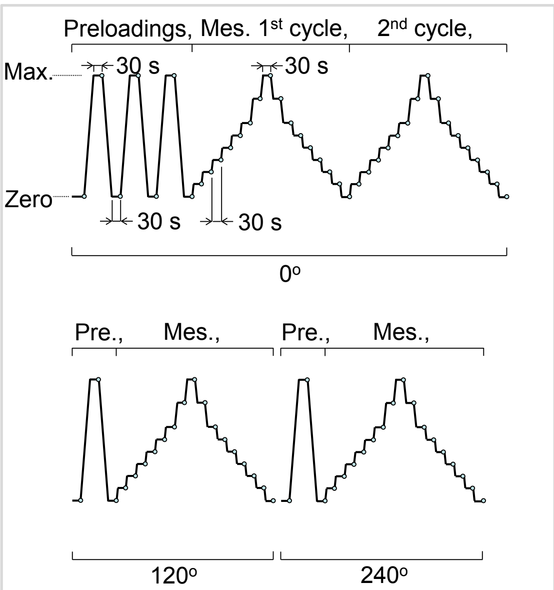

Fig. 4 Loading timetable for the calibration of the RTD.

Experiment 3: Testing verification of the HTD using the TDT as the standard.

2.1 Experiment 1 A newly developed deadweight-type TSM with a rated capacity of 10 N·m was used (10-N·m-DWTSM) [6]. A picture of the machine is shown in Fig. 2. The calibration range is from 10 cN·m to 1000 cN·m. A torque transducer with a torque screwdriver shape (TP-6N-0707, manufactured by Showa Measuring Instruments Inc.) was calibrated with a combination of an amplifier/indicator (MGCplus, amplifier type: ML38, manufactured by HBM GmbH) as the RTD. The rated capacity is 600 cN·m, and the resolution of the RTD r was 9.4 µN·m. A picture of the TP-6N-0707 is shown in Fig. 3.

Because of the limited calibration steps realized by the 10-N·m-DWTSM, calibration was performed in two ranges: from 10 cN·m to 100 cN·m and from 50 cN·m to 600 cN·m. There were eight calibration steps, as follows:

- 10 cN·m, 20 cN·m, 30 cN·m, 40 cN·m, 50 cN·m, 60 cN·m, 80 cN·m, and 100 cN·m,
- 50 cN·m, 100 cN·m, 150 cN·m, 200 cN·m, 300 cN·m, 400 cN·m, 500 cN·m, and 600 cN·m.

According to the guideline for the calibration method JMIF015 [8], at first, two calibration cycles with increasing and decreasing loading steps were conducted after three instances of pre-loading up to the maximum torque at the 0° mounting position. After changing the mounting position, one calibration cycle of increasing and decreasing loading steps was also conducted after one instance of pre-loading at the 120° and 240° mounting positions. The clockwise (CW) and counterclockwise (CCW) torques were calibrated, respectively. Figure 4 shows the loading timetable for Experiment 1.

2.2 Experiment 2 The RTD (TP-6N-0707 + MGCplus: ML38) was used as the reference standard. The calibration range was from 10 cN·m to 600 cN·m. A TDT (TDT-600CN, manufactured by Tohnichi MFG Ltd.) was calibrated by installing the RTD on it (like a HTD). A picture of the TDT-600CN with the installed TP-6N-0707 is shown in Fig. 5. The calibration range specified by the manufacturer is from 20 cN·m to 600 cN·m, but the authors investigated the calibration for one range from 10 cN·m to 600 cN·m in this experiment (the lower limit was extended). The resolution of the TDT r was 0.2 cN·m. There were eight calibration steps, as follows:

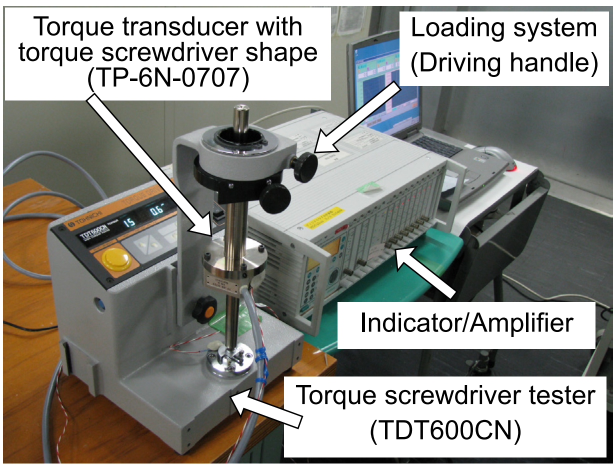

Fig. 5 TDT with the RTW.

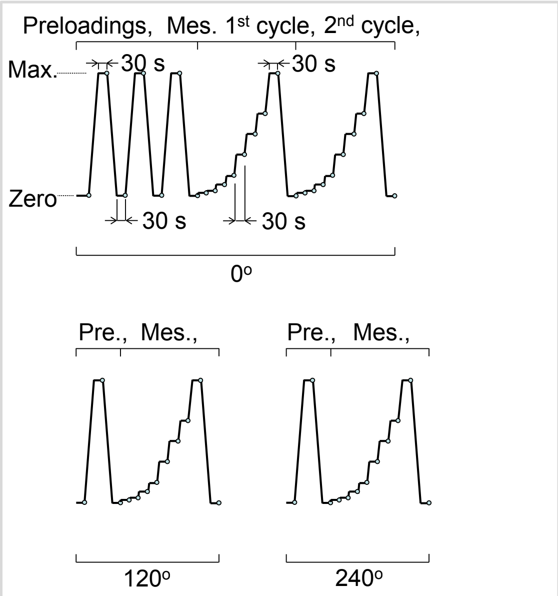

Fig. 6 Loading timetable for the calibration of the TDT.

(a) Indicating type **(b) Setting type**

Fig. 7 HTDs installed on the TDT.

- 10 cN·m, 20 cN·m, 50 cN·m, 100 cN·m, 200 cN·m, 300 cN·m, 400 cN·m, and 600 cN·m.

According to the guideline for the calibration method JMIF019 [9], two calibration cycles with increasing loading steps were conducted after three instances of pre-loading up to the maximum torque at the 0° mounting position. After changing the mounting position of the RTD, one calibration cycle of increasing steps was also conducted after one instance of pre-loading at the 120° and 240° mounting positions. CW and CCW torques were calibrated, respectively. Figure 6 shows the loading timetable for Experiment 2.

2.3 Experiment 3 The TDT (TDT-600CN) was used as the reference standard. The calibration range was from 10 cN·m to 600 cN·m. The FTD-400CN (indicating type, the resolution: 1 cN·m) and RTD-500CN (setting type, the smallest graduation: 5 cN·m) HTDs (both manufactured by Tohnichi MFG Ltd.) were tested by installing them on the

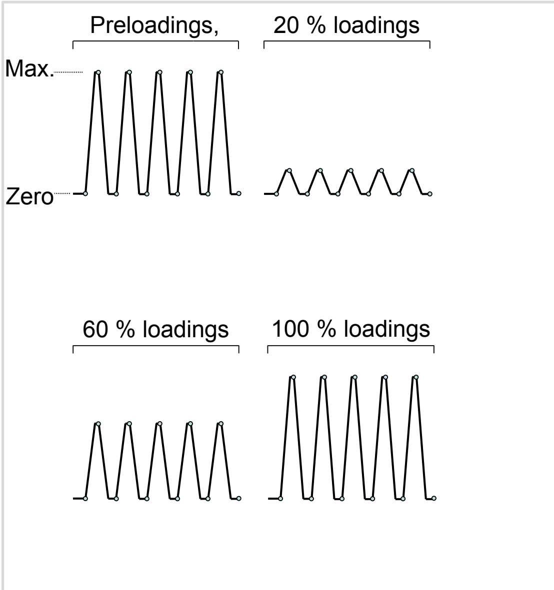

Fig. 8 Loading timetable for the testing verification of the HTDs.

TDT. Figure 7 shows pictures of the FTD-400CN and RTD-500CN installed on the TDT. The tested ranges were from 80 cN·m to 400 cN·m for the FTD-400CN and from 100 cN·m to 500 cN·m for the RTD-500CN.

According to ISO6789, three loading steps of 20 %, 60 %, and 100 % for maximum torque were conducted successively five times after pre-loading at the maximum torque five times. The CW and CCW torques were tested for the FTD-400CN, and only the CW torque was tested for the RTD-500CN. Figure 8 shows the loading timetable for Experiment 3.

3. RESULTS AND DISCUSSION

3.1 Experiment 1 The uncertainty was evaluated according to JCG209S11 [10], which is a guideline for the uncertainty evaluation of calibrations for torque meters and reference torque wrenches issued by the International Accreditation Japan at the National Institute of Testing and Evaluation (IAJapan/NITE: the accreditation body for calibration and testing laboratories in Japan). The relative expanded uncertainty of the calibration is expressed by the following equation:

$$W_{\mathrm{cal\_rtd,i}} = k \cdot \sqrt{w_{\mathrm{rot\_rtd,i}}^{2} + w_{\mathrm{rep\_rtd,i}}^{2} + w_{\mathrm{int\_rtd,i}}^{2} + w_{\mathrm{zer\_rtd,i}}^{2} + w_{\mathrm{res\_rtd,i}}^{2} + w_{\mathrm{tsm,i}}^{2}}\ , \quad \cdots\cdots\cdots\cdots (1)$$

where $w_{\mathrm{rot\_rtd}}$ is the uncertainty contribution for the reproducibility with a change in the mounting position, $w_{\mathrm{rep\_rtd}}$ is that for the repeatability without a change in the mounting position, $w_{\mathrm{int\_rtd}}$ is that due to the interpolation, $w_{\mathrm{zer\_rtd}}$ is that due to a zero error, $w_{\mathrm{res\_rtd}}$ is that due to the resolution, and w_{tsm} is the relative standard uncertainty concerned with the TSM. The “i” indicates the index of the calibration steps. The result does not include the influence of hysteresis.

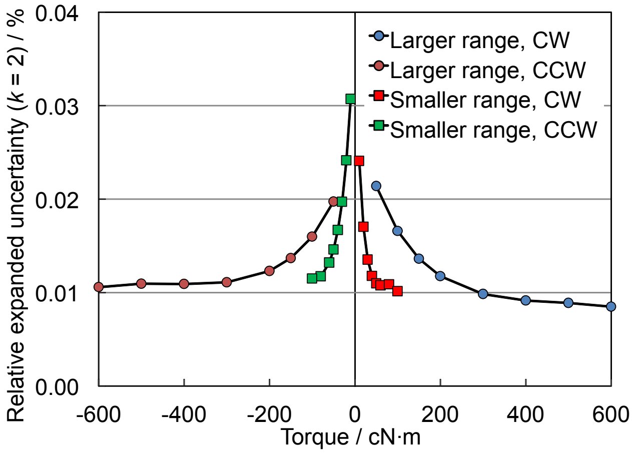

Fig. 9 Uncertainty evaluation results of the calibration for the RTD.

The result of the uncertainty evaluation is shown in Fig. 9. The maximum relative expanded uncertainty for each calibration range was as follows:

10 cN·m – 100 cN·m: CW 0.024 %, CCW 0.031 %,
50 cN·m – 600 cN·m: CW 0.021 %, CCW 0.020 %.

The interpolation equations were calculated and used for the successive calibration of the TDT described in Section 2.2.

3.2 Experiment 2 The uncertainty was evaluated according to JCG209S21 [11], which is a guideline for the uncertainty evaluation of calibrations for torque wrench testers and torque testing machines issued by IAJapan/NITE. Again, the relative expanded uncertainty of the calibration is expressed by the following equation:

$$W_{\text{cal\_tdt,i}} = k \cdot \sqrt{w_{\text{rot\_tdt,i}}^{2} + w_{\text{rep\_tdt,i}}^{2} + w_{\text{int\_tdt,i}}^{2} + w_{\text{zer\_tdt,i}}^{2} + w_{\text{res\_tdt,i}}^{2} + w_{\text{rtd,i}}^{2}} \quad (2)$$

where each uncertainty contribution has the same meaning as in the case of the RTD calibration (Equation (1)), except that w_{rtd} means the relative standard uncertainty concerned with the RTD. In the use of HTDs, the influence of hysteresis does not need to be considered, so the decreasing torque was not examined in Experiment 2.

The result of the uncertainty evaluation is shown in Fig. 10. The maximum relative expanded uncertainties for the various lower limits of the calibration were as follows:

10 cN·m – 600 cN·m: CW 6.6 %, CCW 2.9 %,
20 cN·m – 600 cN·m: CW 2.6 %, CCW 2.0 %,
50 cN·m – 600 cN·m: CW 1.1 %, CCW 0.62 %,
100 cN·m – 600 cN·m: CW 0.75 %, CCW 0.24 %.

In this evaluation, the uncertainty contribution of the interpolation was taken into consideration instead of the indication error; i.e., the authors exchanged the indicated values with the reference values by using the interpolation equations when the TDT was used for the testing of the HTDs described in Section 2.3, although the TDT has a digital indication display (by the direct torque unit expression).

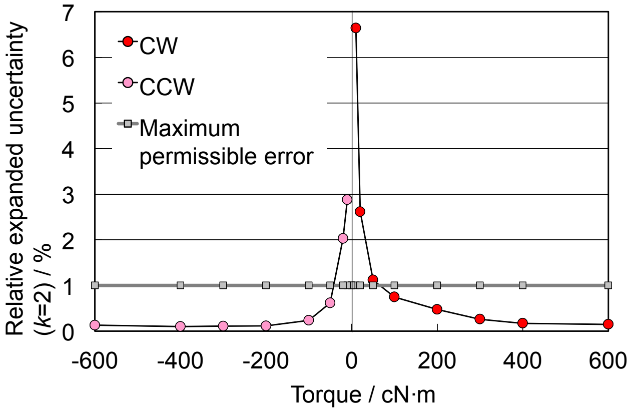

Fig. 10 Uncertainty evaluation results of the calibration for the TDT.

It was found that the uncertainty exceeded 1 %, even if the interpolation equations were used when including a lower limit of 10, 20, or 50 cN·m. Both the users and manufacturers of TDTs should pay attention to the choice of the lower limit and consider the uncertainty. In addition, the authors insist that the normative description of "the maximum permissible uncertainty of the torque tool calibration devices shall be less than 1 %." in ISO6789 should be clarified; i.e., the method of uncertainty evaluation for the TDT calibration should be defined and harmonized.

3.3 Experiment 3 Figure 11 shows test results for two different HTDs. In all of the five successive measurements at each step, the relative deviations were within 6 % of the maximum permissible deviation prescribed in ISO6789 for both the FTD-400CN and RTD-500CN. These HTDs were recognized to conform with ISO6789 because the maximum uncertainty of the TDT was within 1 % in the tested ranges from 80 cN·m to 500 cN·m. However, if the TDT is used, including the lower range from 10 cN·m to 50 cN·m as described in Section 1, the testing results must be out of conformity with ISO6789.

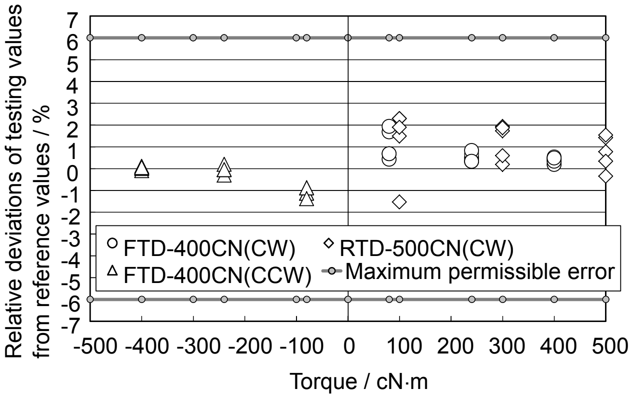

Fig. 11 Testing results for HTDs.

4. CONCLUSION

The authors experimentally realized a complete calibration chain from the national torque standard to the hand torque screwdriver (HTD), where the appropriate calibration methods and uncertainty evaluations were applied.

If torque screwdriver testers (TDTs) are used as reference standards for the testing of HTDs, testing organizations should pay attention to the fact that the calibration uncertainties of the TDTs must be within the maximum permissible uncertainty prescribed in ISO6789 for the entire testing range of the HTDs.

Here, as shown in Fig. 1, first-grade accredited laboratories may calibrate RTDs with an uncertainty of approximately 0.2 % for calibrators or users of TDTs instead of the values presented in Section 3.1 (approx. 0.02 % – 0.03 %), which were directly obtained by NMIJ using the TSM. The authors, therefore, insist that it would be sufficiently possible for the Japanese industry to establish the hierarchy proposed in Fig. 1.

5. REFERENCES

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