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STUDY ON REFERENCE TORQUE WRENCH TESTED BY DEADWEIGHT TORQUE STANDARD MACHINE

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Abstract:
The reference torque wrench is usually calibrated and verified on the reference torque standard machine, then traceability to the deadweight standard machine. This paper describes the method of directly calibrating and verifying the reference torque wrench on the deadweight torque standard machine. Specially tool and adapters are designed, the arm length can be adjusted, and the installation position can be changed according to needs, which fully meets the requirements of German DKD-R 3-7 and Chinese calibration guideline JJG 1103:2014. The differences and similarities between Chinese and German calibration methods are also compared and discussed.

Keywords: reference torque wrench; JJG 1103:2014; traceability of reference torque wrench

1. INTRODUCTION

For the torque generated by lateral force, as early as the beginning of this century, the German National Metrology Institute PTB carried out special research, combined with the test data, and finally issued a calibration guide: DKD-R 3-7 [1]. In China, since 2013, the National Force and Hardness Measurement Technical Committee is responsible for technical demonstration. Combined with the German calibration guidelines, with the accumulation of a large amount of data, the National Institute of Metrology of China is the main drafting unit. The JJG 1103: Standard Torque Wrench Calibration Guideline was compiled and officially promulgated and implemented in 2014 [2].

This paper describes the method of deadweight torque standard device to calibrate the reference torque wrench directly.

2. EQUIPMENT

In this chapter all the equipment is described.

2.1. Equipment to be Tested

In this study, a reference torque wrench, model Dm-TS, produced by GTM, Germany, with the capacity of 1 000 N·m and an accuracy level of 0.1 was used, as shown in Figure 1. The amplifier connected with the torque wrench is type CFA225-P and its accuracy is 0.002 5 %.

Figure 1: The reference torque wrench Dm-TS

The deadweight torque standard machine used is produced by Kunshan Innovation Technology Testing Instrument Co., Ltd., and has a capacity of 1 000 N·m. The measurement range is from 10 N·m to 1 000 N·m, with an accuracy class of 0.03 %. The machine is shown in Figure 2.

Figure 2: Deadweight torque machine of 1 000 N·m

2.2. Adapters and Special Tools

Since the torque standard machine is usually used to calibrate the torque sensor, the hardware connection interface on the machine is made according to the size of the two ends of the normal torque sensor. Now the reference torque wrench needs installing on the torque standard machine. The sharp "Square" of the torque wrench needs an adapter. The arm of the wrench also needs to fit on the machine. Thus, the adapters and special tools are designed and manufactured for it. The length of the arm also needs adjusting according to the calibration guidelines.

The special tools and adapters are shown in Figure 3, Figure 4, and Figure 5.

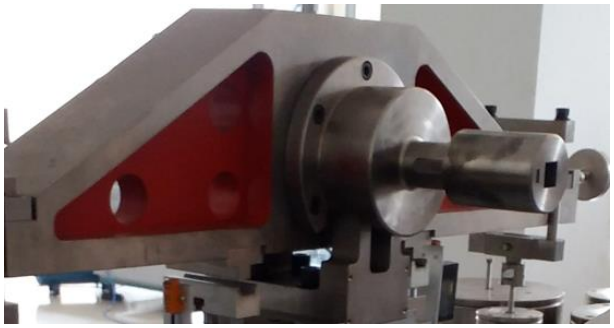

Figure 3: The adapters on the machine

Figure 4: The special tools to fit the wrench

Figure 5: The length can be adjusted

Originally, the sharp of the black screw, which react lever arm, is a point. But there are two aluminium plates to use, to protect the lever of the torque wrench. It might influence the lever length. Improvement was done afterwards.

2.3. Difference About the Standard Torque Machine in Germany

Here we can see the reference torque wrench was mounted on horizontal, while the reference torque wrench in Germany normally is mounted on vertical on the standard machine.

In PTB, the standard machine which is used to perform the calibration for reference torque wrenches is a reference torque standard machine, as shown in Figure 6.

Figure 6: Standard torque machine at PTB

3. DIFFERENCE BETWEEN GERMAN GUIDELINE AND CHINESE GUIDELINE

Germany guideline DKD-R 3-7 has the highest accuracy level of 0.05, while China's calibration guideline JJG 1103 has highest level of 0.1. Since China's calibration system follows a 3-fold relationship. The highest accuracy level of the torque wrench tester is 0.3, so the highest level of the reference torque wrench is enough to reach 0.1, no need to go higher. The classifications of DKD-R 3-7 and the Chinese guideline are given in Table 1 and Table 2.

Table 1: Specification of DKD-R 3-7

Class	b, b_1	b'	f_0	h	f_a, f_q
	/ %				
0.05	0.05	0.025	0.0125	0.063	±0.025
0.1	0.10	0.05	0.025	0.125	±0.05
0.2	0.20	0.10	0.05	0.25	±0.10
0.5	0.50	0.25	0.125	0.63	±0.25
1	1.00		0.25	1.25	±0.5
2	2.00		0.50	2.50	±1.0
5	5.00		1.25	5.0	±2.5

In Table 1:

- b is reproducibility under maximum lever length
- b_1 is reproducibility under maximum and minimum lever length
- b' is repeatability under maximum lever length
- f_0 is zero after load release
- h is hysteresis
- f_a and f_q are relative deviation and interpolation

Table 2: Specification of JJG 1103-2014

Class	Z_r	b	b_1	b'	S_b	δ	h	Z_d	I_p
	/ %								
0.1	0.01	0.1	0.1	0.1	0.1	0.1	0.15	0.01	0.1
0.2	0.02	0.2	0.2	0.2	0.2	0.2	0.30	0.02	0.2
0.3	0.03	0.3	0.3	0.3	0.3	0.3	0.45	0.03	0.3
0.5	0.05	0.5	0.5	0.5	0.5	0.5	0.75	0.05	0.5

In Table 2:

- b, b_1, b' and h are the same as in DKD-R 3-7
- Z_d is zero without load
- Z_r is zero after load release
- δ and I_p are relative deviation and interpolation

The key difference is S_b: long-term stability in Chinese guideline.

From the tables, Chinese guideline has one more specification than Germany: long-term stability. This is a key technical data which Chinese people take more seriously. In China, metrology is divided into two systems: verification and calibration. Different from calibration, the verification object depends on whether the long-term stability of six months or one year meets the standard. This also requires the standard equipment used to have corresponding stability. In Germany, measurement only has the calibration system, so there is no requirement for the index of stability.

Normally a verification certificate was issued after two tests, with an interval of six months or one year. The calibration certificate is only for one test. The uncertainty of the official certificate includes the long-term stability. In this paper the uncertainty was not combined because there is not interval in this study.

The test procedure of these two guidelines is the same. Figure 7 and Figure 8 show the procedures. Y-axis is the load (torque) and X-axis is the time, when different positions need to be changed.

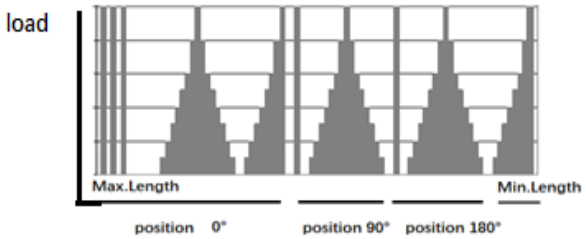

Figure 7: The procedure in DKD-R 3-7

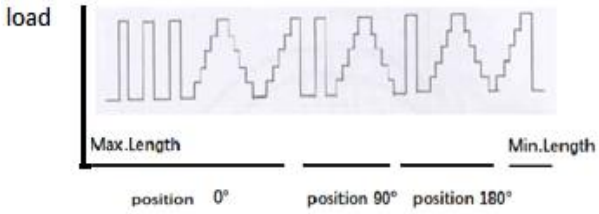

Figure 8: The procedure in JJG 1103

4. TEST DATA AND ANALYSIS

The reference torque wrench was tested on this deadweight torque standard machine and value of mV/V was recorded. Full capacity of the transducer was not tested because the goal to obtain the value of mV/V, and the linearity of the transducer also need be proved. The measurement is only anticlockwise. The data is shown in Table 3.

Table 3: Data of measurements

Torque / N·m	Test 1 0° / mV/V	Test 2 0° / mV/V	Test 4 90° / mV/V	Test 6 180° / mV/V
0	0.000 00	0.000 00	0.000 00	0.000 00
100	-0.399 98	-0.400 02	-0.399 99	-0.399 87
200	-0.799 93	-0.800 02	-0.800 28	-0.799 80
300	-1.199 92	-1.200 04	-1.200 37	-1.199 64
400	-1.600 06	-1.600 12	-1.600 14	-1.599 60

Then the repeatability and reproducibility were calculated, as Table 4.

Table 4: Data of measurements

Torque / N·m	Repeatability / %	Reproducibility / %
100	-0.01	-0.03
200	-0.01	-0.06
300	-0.01	-0.06
400	0.00	-0.03

Afterwards the real test was performed. The measurement was recorded as N·m instead of mV/V. Thus, the deviation between reference torque wrench and the standard machine can be compared and calculated. All the data is shown in Table 5.

Table 5: Data of measurements in N·m

Torque step / N·m	Measurement / N·m	Deviation / %
100	99.97	-0.03
200	199.91	-0.05
300	299.85	-0.05
400	399.84	-0.04
500	499.77	-0.05
600	599.72	-0.05
700	699.68	-0.05
800	799.62	-0.05
900	899.47	-0.06
1000	999.29	-0.07

The repeatability and reproducibility are better than 0.1 %, and the indication deviation is also better than 0.1 %.

5. SUMMARY

From the test data, the standard torque wrench of 0.1 precision level is tested on the deadweight torque standard machine, and the repeatability and reproducibility are better than the index of 0.1 %, and the indication error is also better than 0.1 %.

The biggest difference between the German Calibration Guide DKD-R 3-7 and the Chinese National Verification Regulation JJG 1103-2014 is that the accuracy level is different. In particular, the Chinese metrology institutions attach great importance to long-term stability indicators.

In Germany, the standard torque wrench is often installed vertically on the torque standard machine, while in China, the standard torque wrench is often installed horizontally. It is recommended to do special research and discussion on the impact of these two different installation methods on the measurement results.

What is the influence of the error between the reference torque standard machine and the deadweight torque standard machine for the measurement of the same reference torque wrench? It is recommended to make comparison tests of them.

6. REFERENCES

[1] DKD-R 3-7, “Statische Kalibrierung von anzeigenden Drehmomentschlüsseln”. Online [Accessed 20220916] https://www.ptb.de/cms/fileadmin/internet/dienstleistungen/dkd/archiv/Publikationen/Richtlinien/DKD-R_3-7_2018.pdf

[2] JJG 1103:2014, “Reference Torque Wrench Verification Regulations”.