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INTE-COMPARISON OF TORQUE STANDARDS IN RANGE OF 20 N.M UP TO 2000 N.M BETWEEN KRISS AND NIS

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Abstract: An international comparison of torque standards was conducted between KRISS and NIS in the range of 20 N.m up to 2000 N.m. Three high-performance torque transducers measuring "pure torque" were used as transfer devices with the same amplifier. Three transducers, with rated capacities of 50 N.m, 1000 N.m and 2000 N.m were transferred from the NIS to the KRISS. Analysis reveals that all results of KRISS and NIS are equivalent to each other within their CMCs.

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Keywords: Torque Standards, Inter-comparison

1. INTRODUCTION

The comparison on torque in the range of 0 N.m, 20 N.m, 50 N.m, 500 N.m, 1000 N.m, and 2000 N.m was organized and conducted between two laboratories, Korea Research Institute of Science and Standards (KRISS) and National Institute of Standard (NIS) in Egypt. The purpose of this comparison is to provide a link to CCM.T-K1 of the national torque standards in Egypt so that NIS can achieve the degree of equivalence of the CMCs of his torque standards. KRISS, who joined CCM.T-K1 key comparison, plays a role of a link laboratory. Details of this comparison will be described in two sections. The results of comparison in the range of 0 N.m, 500 N.m and 1000 N.m, which will be linked to those of CCM.T-K1, are described in Section 2. The results of additional comparison in the range of 0 N.m, 20 N.m, 50 N.m, 1 kN.m and 2 kN.m are described in Section 3. NIS used a different torque standard machine when conducting the additional comparison experiments.

2. COMPARISON ON.MEASURAND TORQUE AT 0 N.M, 500 N.M AND 1000 N.M

2.1 Participants' details

The participating laboratories are KRISS (pilot) and NIS (Egypt). Their torque standard machines (TSMs) are listed in Table 1.

Table 1: Participated institutes and torque standard machines

Institute	Torque Standard Machine		
	Capacity / kN.m	Type	Relative standard uncertainty
KRISS	2	Deadweight	2.5×10^{-5}
NIS	1	Comparator (Horizontal)	3.0×10^{-4}

2.2 Comparison Protocol

The protocol of this CCM.T-K1.3 basically is similar to that of CCM.T-K1 key comparison [1]. The differences are as follows;

1) One travelling standard with 1000 N.m capacity was used to compare 0 N.m, 500 N.m, and 1000 N.m torques due to practical limitation.
2) We strictly followed the measurement sequence of CCM.T-K1 except the time interval. The time interval was reduced to 5 minutes in this comparison from 6 minutes in CCM.T-K1 in order to complete the measurement sequence more quickly while minimizing the creep effect of the transfer standard.
3) The same bridge amplifier was used for indications of all travelling standards for both laboratories. Thus, a bridge calibration unit was not used to calibrate the amplifier. We expect that the correction due to the long-term drift of the amplifier itself can be ignored.

2.3 Traveling standard

A torque transducer with a capacity of 1000 N.m type TN (belonging to NIS) was used with DMP40S2 bridge amplifier, both from HBM.

2.4 Comparison formation

The measurement was carried out one time for each participant due to the practical limitation. To reduce the effect of long-term stability of the travelling standard, the time interval between two successive measurements was set to approximately one month, which includes transportation time, thermal stabilization time of the travelling standard at each laboratory.

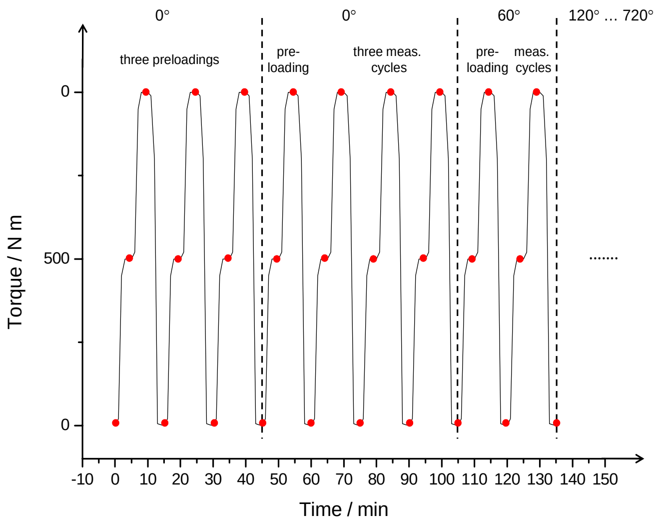

Figure 1: Diagram of the measurement sequence of the torque KC.

2.5 Measurement results

The measurement result is the mean deflection calculated from the 12 original readings measured in 12 orientations (60° to 360° for two rotations) for each of the two torque steps and the two directions. The measurement uncertainty has to be calculated for the mean deflectioN.measured with the transducer and the DMP 40. No correction for amplifier, temperature, air humidity or creep was applied in these results. We expect that these effects could be negligible compared to the relative uncertainty of 0.06 % of NIS TSM based on the report of CCM.T-K1 [1]. The uncertainty was calculated according to the protocol of CCM.T-K1 and the same worksheets were used to report the results. The measurement results are listed in Table 2.

2.6 Comparison results

The analysis was performed according to [2] in order to test the equivalence of reported data between two NMIs. We followed the Procedure A of [2].

2.6.1 Weighted mean and χ2 test

Table 3 includes KRISS values (xKRI) and NIS values (xNIS) and weighted means (xweighted) with their standard uncertainties (uKRI, uNIS, uweighted) for clockwise and anticlockwise torque at 500 N.m and 1000 N.m. It also includes the observed chi-squared values χ^2_{obs} as well as decisions made for the equivalence test, denoted by Pass or Fail. If $\chi^2_{0.05}(\nu = 1) = 3.841 > \chi^2_{obs}$ satisfies, the measurement results are consistent. The claimed uncertainties of NIS are approximately ten times bigger than those of KRISS so that the weighted means are almost equal to the reported values of KRISS.

It can be recognized that all measurement results passed the equivalence test with exceptionally good fit (i.e., χ^2_{obs} values are much smaller than the $\chi^2_{0.05}(\nu = 1)$ value for all ranges).

2.6.2 Degree of equivalence

The degree of equivalence to the weighted mean for each lab was calculated from

$$d_i = x_i - x_{\text{weighted}} \qquad (1)$$

$$u(d_i) = \sqrt{u^2(x_i) - u^2(x_{\text{weighted}})} \qquad (2)$$

$$U(d_i) = 2u(d_i) \qquad (3)$$

The degree of equivalence between KRISS and NIS was calculated from

$$d_{i,j} = x_i - x_j \qquad (4)$$

Table 2: Reported deflections and expanded uncertainty (*K*=2)

Institute	Date	Clockwise torque			
		500 N.m		1000 N.m	
		Deflection (mV/V)	Relative expanded uncertainty ($\times 10^{-5}$)	Deflection (mV/V)	Relative expanded uncertainty ($\times 10^{-5}$)
KRISS	2010-11	0.877832	5.8	1.755772	5.8
NIS	2010-12	0.877753	60	1.755796	60
Institute	Date	Counterclockwise torque			
		500 N.m		1000 N.m	
		Deflection (mV/V)	Relative expanded uncertainty ($\times 10^{-5}$)	Deflection (mV/V)	Relative expanded uncertainty ($\times 10^{-5}$)
KRISS	2010-11	-0.877804	5.7	-1.755718	5.7
NIS	2010-12	-0.877774	60	-1.755793	60

Table 3: KRISS and NIS values and their weighted mean values with their uncertainties together with the consistency test at 500 N.m and 1000 N.m for both directions (clockwise and anticlockwise).

M (N.m)	x_{KRI} (mV/V)	u_{KRI} (mV/V)	x_{NIS} (mV/V)	u_{NIS} (mV/V)	$x_{weighted}$ (mV/V)	$u_{weighted}$ (mV/V)	χ^2_{obs}	Decision
Clockwise								
500	0.877832	0.000025	0.877753	0.000264	0.877831	0.000025	0.089	Pass
1000	1.755772	0.000051	1.755796	0.000527	1.755772	0.000050	0.002	Pass
Counterclockwise								
-500	-0.877804	0.000025	-0.877774	0.000264	-0.877803	0.000025	0.013	Pass
-1000	-1.755718	0.000049	-1.755793	0.000527	-1.755719	0.000049	0.020	Pass

Table 4: Degree of equivalence for KRISS and NIS and between KRISS and NIS with their uncertainties. The values in parenthesis indicate relative values in percentage with respect to the weighted means.

M (N.m)	d_{KRI} mV/V (%)	$U(d_{KRI})$ mV/V (%)	d_{NIS} mV/V (%)	$U(d_{NIS})$ mV/V (%)	$d_{NIS,KRI}$ mV/V (%)	$U(d_{NIS,KRI})$ mV/V (%)
Clockwise						
500	0.000001 (0.000)	0.000005 (0.001)	-0.000078 (-0.009)	0.000525 (0.060)	-0.000079 (-0.009)	0.000530 (0.060)
1000	0.000000 (0.000)	0.000010 (0.001)	0.000023 (0.001)	0.001049 (0.060)	0.000024 (0.001)	0.001059 (0.060)
Counterclockwise						
-500	0.000000 (0.000)	0.000005 (-0.001)	0.000029 (-0.003)	0.000525 (-0.060)	0.000030 (-0.003)	0.000530 (-0.060)
-1000	0.000001 (0.000)	0.000009 (-0.001)	-0.000075 (0.004)	0.001049 (-0.060)	-0.000075 (0.004)	0.001058 (-0.060)

$$u(d_{i,j}) = \sqrt{u^2(x_i) + u^2(x_j)} \quad (5)$$

$$U(d_{i,j}) = 2u(d_{i,j}) \quad (6)$$

Where, i and j is the index of labs. Table 4 shows the results. All results indicate that $d_i < U(d_i)$ and $d_{i,j} < U(d_{i,j})$, implying that they are equivalent to each other.

3. COMPARISON ON.MEASURAND TORQUE AT 0 N.m, 20 N.m, 50 N.m, 1 kN.m and 2 kN.m

3.1 Participants

Torque comparisons were conducted at 0 N.m, 20 N.m, 50 N.m, 1 kN.m and 2 kN.m using the same procedure and two different travelling standards with a capacity of 50 N.m and 2 kN.m, respectively. The TSMs used in these comparisons are listed in Table 5.

Table 5: Torque standard machines used in the torque comparison

Institute	Torque Standard Machine		
	Capacity / kN.m	Type	Relative standard uncertainty
KRISS	2	Deadweight	2.5×10^{-5}
NIS	3	Comparator (Vertical)	2.5×10^{-4}

3.2 Travelling standard

Two different travelling standards with a capacity of 50 N.m (type TN from HBM) and 2 kN.m (Type DmTN from GTM) were used with DMP40S2 bridge amplifier.

3.3 Comparison results

The reported results are listed in Table 6 and 7, respectively.

Table 6: Reported deflections and expanded relative uncertainties (k = 2) at 20 N.m and 50 N.m torques

Institute	Date	Clockwise torque			
		20 N.m		50 N.m	
		Deflection (mV/V)	Relative expanded uncertainty ($\times 10^{-5}$)	Deflection (mV/V)	Relative expanded uncertainty ($\times 10^{-5}$)
KRISS	2010-09	0.609096	5.0	1.522834	5.0
NIS	2010-12	0.609093	50	1.522825	50
Institute	Date	Counterclockwise torque			
		20 N.m		50 N.m	
		Deflection (mV/V)	Relative expanded uncertainty ($\times 10^{-5}$)	Deflection (mV/V)	Relative expanded uncertainty ($\times 10^{-5}$)
KRISS	2010-09	-0.609135	5.2	-1.522879	5.0
NIS	2010-12	-0.609072	50	-1.522788	50

Table 7: Reported deflections and expanded relative uncertainties (k = 2) at 1 kN.m and 2 kN.m torques

Institute	Date	Clockwise torque			
		1 kN.m		2 kN.m	
		Deflection (mV/V)	Relative expanded uncertainty ($\times 10^{-5}$)	Deflection (mV/V)	Relative expanded uncertainty ($\times 10^{-5}$)
KRISS	2010-11	1.001399	5.2	2.003316	5.1
NIS	2010-12	1.001329	50	2.003278	50
Institute	Date	Counterclockwise torque			
		1 kN.m		2 kN.m	
		Deflection (mV/V)	Relative expanded uncertainty ($\times 10^{-5}$)	Deflection (mV/V)	Relative expanded uncertainty ($\times 10^{-5}$)
KRISS	2010-11	-1.001658	5.1	-2.004343	5.2
NIS	2010-12	-1.001528	50	-2.004563	50

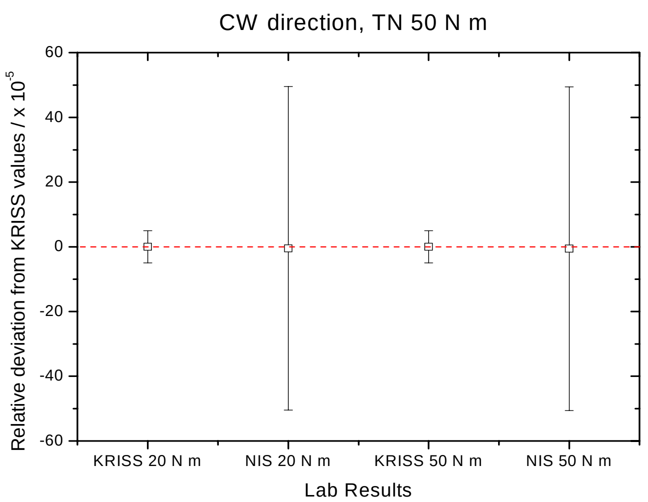

Figure 2: Comparison results at 20 N m and 50 N m in CW direction

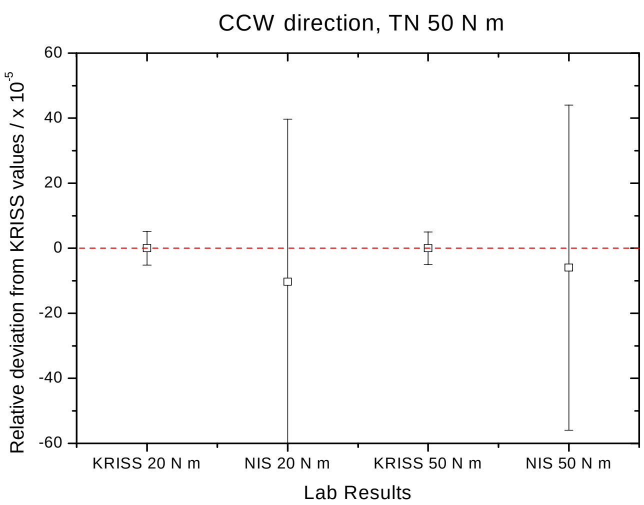

Figure 3: Comparison results at 20 N m and 50 N m in CCW direction

As shown in Table A3 and A4, the claimed uncertainties of KRISS are almost ten times better than those of NIS. Thus, it would be enough to decide the equivalence of the results by simply comparing results between them.

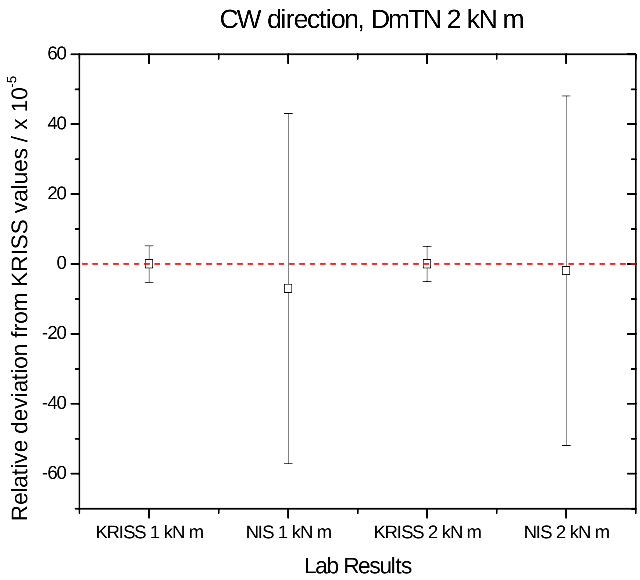

Figure 4: Comparison results at 1 kN m and 2 kN m in CW direction

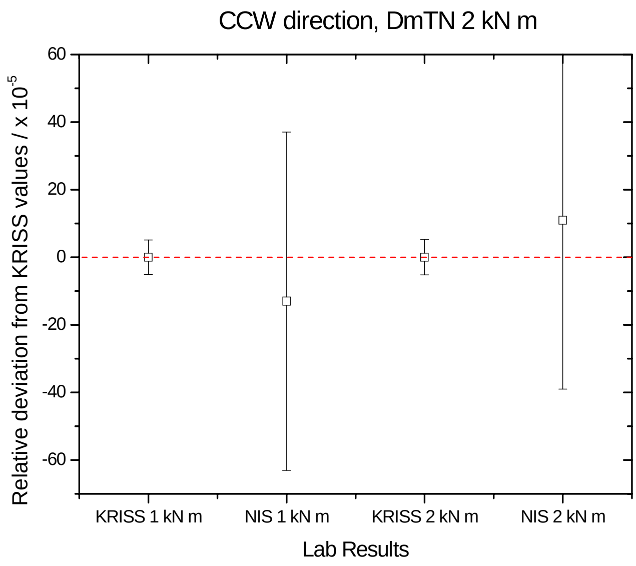

Figure 5: Comparison results at 1 kN m and 2 kN m in CCW direction

4. SUMMARY

A bilateral comparison between KRISS and NIS was conducted at the torques of 0 N.m, 20 N.m, 50 N.m, 500 N.m, 1000 N.m and 2000 N.m. As shown in Table 3 and 4 and Figure 2, 3, 4 and 5, Analysis reveals that differences of all results between KRISS and NIS are very small compared to NIS's declared uncertainties, suggesting that both results are equivalent to each other with high reliability.

5. REFERENCES

[1] Dirk Röske et al, 2009 "Final report on the torque key comparsion CCM.T-K1. Measurand Torque: 0 N.m, 500 N.m, 1000 N.m".
[2] M. G: Cox, 2002 "The evaluation of key comparison data," *Metrologia*, 2002, **39**, 589-595.