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PERFORMANCE EVALUATION OF NIS NEW REFERENCE TORQUE STANDARD MACHINE

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Abstract – A new design of 3 kNm reference torque standard machine was considered. The machine performance is evaluated via inter-laboratory comparison technique using previously calibrated reference torque transducers, one set at the National physical laboratory of Germany (PTB) and the other one calibrated at the accredited laboratory of the English company Norbar. Two loading schemes are used. The first one is slow (5 minutes per calibration step) while the second is a fast one (45 seconds per calibration step). The calibration results revealed good agreement between the designed machine and those of both the PTB and English Norbar.

Keywords: torque machine, comparison, uncertainty

1. Introduction

Two types of evaluation are herein carefully discussed. These are intercomparison calibrations and uncertainty evaluation. Intercomparison calibrations are simply recalibrations for the available NIS set of high accuracy torque transducers of 10, 50, 200 and 1000 Nm. These transducers were previously calibrated by PTB 20 Nm and 1 kNm torque standard machines according to DIN 51309 standard specifications [1]. Intercomparison calibrations was carried out also on low accuracy torque transducer with capacity of 2.5 kNm which was previously calibrated by unsupported beam calibration machine, Norbar company (England) [2] according to BS 7882 standard specification [3]. Therefore the same calibration procedure was utilized. On the other hand NAMAS M3003 standard specification [4] was followed to evaluate the measurement uncertainty on the NIS torque standard machine from the individual sources of uncertainty.

2. Intercomparison calibrations

As the NIS 3 kNm torque standard machine utilizes the comparison procedure in calibration and it is capable to perform calibrations either in continuous or in step by step method. A set of recalibrations (step by step and continuous) were carried out by the available set of high accuracy reference transducers by comparing recalibrations results with the latest calibrations given by PTB. In order to check the machine performance up to 2.5 kNm, recalibration was also carried out by available low accuracy torque transducer with capacity of 2.5 kNm by comparing recalibration results with the transducers latest calibration.

2.1. Recalibration with PTB

Recalibration was carried out using high accuracy set of torque transducers of 10, 50, 200 and 1000 Nm capacity in both clockwise and anticlockwise directions.

It was carried out in accordance with DIN 51309 standard specification as shown in figure 1 (10%, 20%, 30%, 40%, 50%, 60%, 80%, 100% of full scale) with two methods. The first employed step by step method with time table as bilateral comparison between PTB and NIS [5] (about 5 minutes per step). The second employed continuous method with about 45 second per step. The major advantage of continuous method is decreasing the calibration time to an order of magnitude less than the time of the step by step method.

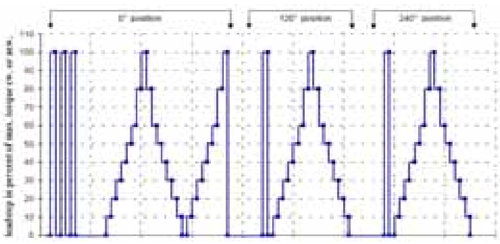
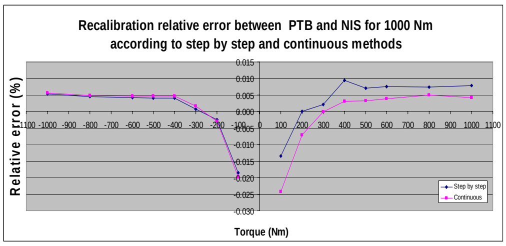


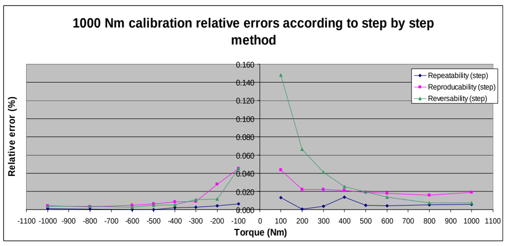
Fig. 1: Loading cycle of DIN 51309 standard specification.

Comparing recalibrations results for both step by step and continuous methods with the latest calibrations given by PTB. Indicating device and data acquisition system affect the measurement uncertainty. Therefore, it must be performed using a synchronized two channels high resolution indicating device with computerized measurement recording. Accordingly, a synchronised indicating device DMP 40S2 with maximum resolution of 1000000 counts for transducer output of 2 mV/V with uncertainty better than $4x10^{-6}$ was used. An interface program based on GBIP card and lab view software was developed for recording the two channels readings at the same time.

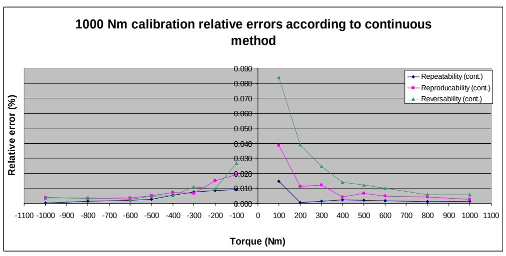
The set of recalibrations according to DIN 51309 standard specifications was carried out in clockwise and anticlockwise directions for NIS transducers. The results of these recalibrations are presented in the form of the relative deviation between the mean value of the absolute calibration procedure of PTB, and recalibration using either step by step or continuous methods at NIS. Furthermore, recalibrations relative errors including relative repeatability, reproducibility and reversibility errors are presented as shown in figures from 2 to figure 5.



a) Relative error % versus torque for both step by step and continuous calibration.

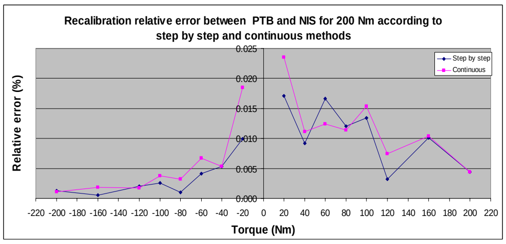


b) Relative error versus torque showing repeatability, reproducibility and reversibility relationships for step by step calibrations.

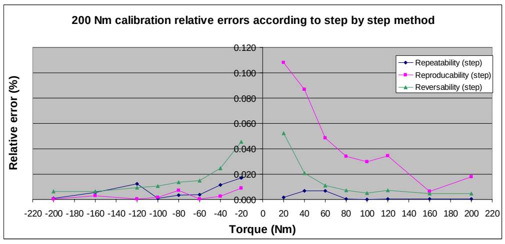


c) Relative error versus torque showing repeatability, reproducibility and reversibility relationships for continuous calibrations.

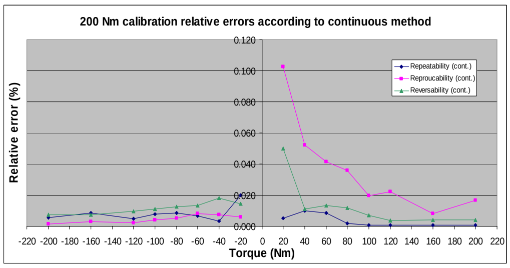
Fig. 2: Recalibration relative error between PTB and NIS for 1000 Nm
a) according to step by step and continuous method,
b) relative errors according to step by step method,
c) relative errors according to continuous method.



a) Relative error % versus torque for both step by step and continuous calibration.

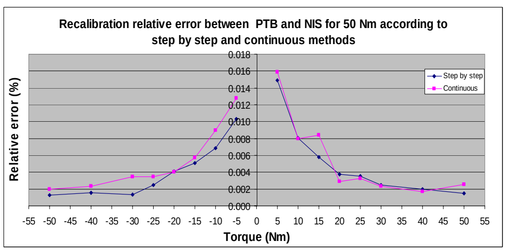


b) Relative error versus torque showing repeatability, reproducibility and reversibility relationships for step by step calibrations.

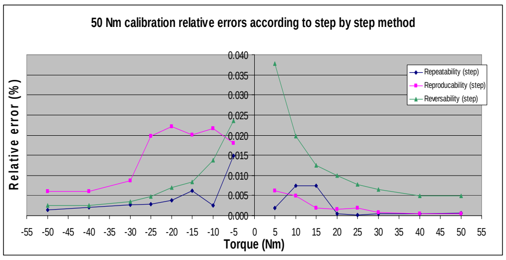


c) Relative error versus torque showing repeatability, reproducibility and reversibility relationships for continuous calibrations.

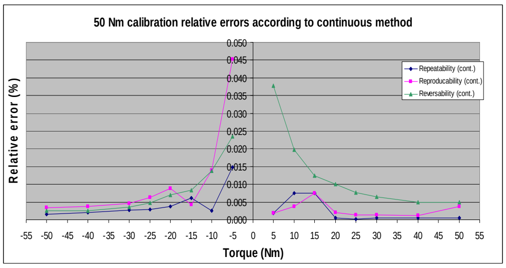
Fig. 3: Recalibration relative error between PTB and NIS for 200 Nm
a) according to step by step and continuous method,
b) relative errors according to step by step method,
c) relative errors according to continuous method.



a) Relative error % versus torque for both step by step and continuous calibration.

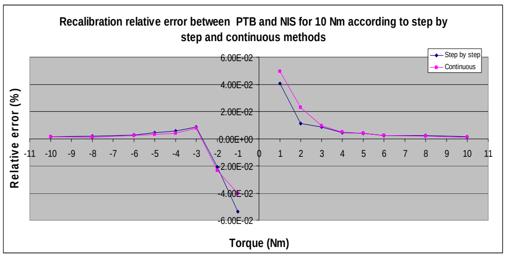


b) Relative error versus torque showing repeatability, reproducibility and reversibility relationships for step by step calibrations.

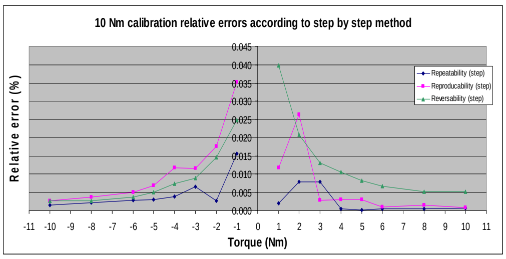


c) Relative error versus torque showing repeatability, reproducibility and reversibility relationships for continuous calibrations.

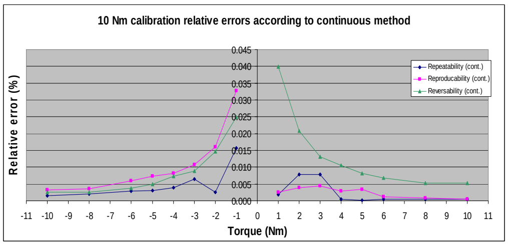
Fig. 4: Recalibration relative error between PTB and NIS for 50 Nm
a) according to step by step and continuous method,
b) relative errors according to step by step method,
c) relative errors according to continuous method.



a) Relative error % versus torque for both step by step and continuous calibration.



b) Relative error versus torque showing repeatability, reproducibility and reversibility relationships for step by step calibrations.



c) Relative error versus torque showing repeatability, reproducibility and reversibility relationships for continuous calibrations.

Fig. 5: Recalibration relative error between PTB and NIS for 10 Nm
a) according to step by step and continuous method,
b) relative errors according to step by step method,
c) relative errors according to continuous method.

These comparisons show that; the maximum relative deviation from PTB calibrations in the range from 2 Nm up to 1 kNm is of order $2x10^{-4}$ for step by step method and $2.4x10^{-4}$ for continuous method. For 1 Nm measuring range the relative deviation is of order $5x10^{-4}$ for both step by step and continuous methods.

Recalibration relative errors for step by step and continuous method can be tabulated as shown in table 1. These comparisons showed that there is a good agreement between NIS torque standard machine and PTB torque standard machine(s).

Table 1: Recalibration relative errors between PTB and NIS from 1 Nm up to 1 kNm.

Relative error	Step by step method	Continuous method
Repeatability	$1.7x10^{-4}$	$2x10^{-4}$
Reproducibility	$1.1x10^{-3}$	$1x10^{-3}$
Reversibility	$1.5x10^{-3}$	$5x10^{-4}$

2.2. Recalibration with Norbar (England)

Recalibration was carried out by available low accuracy torque transducer with capacity of 2.5 kNm with its indicating device (torque tool tester) which was supplied and calibrated at Norbar laboratory, England, and accredited from the United Kingdom Accreditation Services (UKAS). The test is based on comparing recalibration results with its latest calibration to check machine behaviour up to 2.5 kNm torque.

Recalibration according to BS 7882 standard was carried out in clockwise direction for NIS transducer. The results of this recalibration are presented in the form of the relative deviation between the mean value of the calibration procedure of Norbar and recalibration continuous method at NIS. Furthermore, recalibrations relative repeatability error are presented as shown in figure 6.

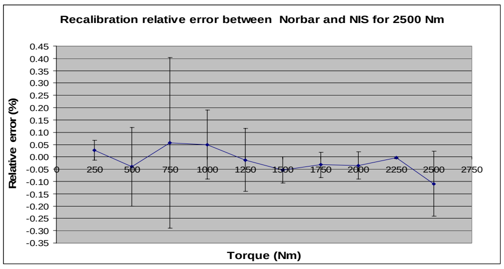


Fig. 6: Recalibration relative error between Norbar and NIS for 2.5 kNm according to continuous method and related repeatability error.

This comparison show that; the maximum relative deviation from Norbar calibration in range from 250 Nm up to 2.5 kNm is of order 1.1×10^{-3} (at 2.5 kNm) for continuous method with relative repeatability error of 1.3×10^{-3}. This relatively high deviation and error is due to low accuracy of the used torque transducer.

This comparison shows that there is a good agreement between NIS torque standard machine and Norbar torque standard machine.

3. Uncertainty evaluation

According to NAMAS M3003 standard specification [4], uncertainty can estimated from: Reference torque transducers uncertainty (U_{ref}) was obtained from the calibration carried out at PTB-Germany. Calibration results showed that the reference torque transducers have a relative expanded uncertainty less than 2×10^{-4} related to the transducer measured torque value from 10% to 100% of the nominal torque.

Relative uncertainty of misalignment error (U_{ali}) is increased by 3×10^{-5} relative to the transducer readings [6] for horizontal machines and it was assumed to be the same for vertical machines. Indicating device resolution, stability, and synchronization influence (U_{indi}) was checked and found to be too small (2×10^{-6}) [7]. Recalibrations creep (U_{creep}) effect (5×10^{-7} of full scale). Drift was calculated from the difference between the last two calibration certificates and it was fount that the relative uncertainty (U_{drift}) is 1×10^{-4}. The influence of oscillations (due to gear rotation or backlash) on readings (U_{osci}) is smaller than 1×10^{-5} of the reading [8].

Finally, temperature change during recalibrations and mean temperature shift from PTB may affect the measurement uncertainty (U_{temp}). From TN torque transducer data sheet it was found that, the effect of temperature of 10°K on the output signal and the output zero signal is 0.02%. During recalibration measurements in NIS torque laboratory which has controlled environmental conditions, it was found that the temperature differs ± 1°K from PTB calibration, this change introduce relative uncertainty about 2×10^{-4}.

Relative expanded uncertainty (%)

$$= 2x\sqrt{(U_{ref}^2 + U_{ali}^2 + U_{indi}^2 + U_{creep}^2 + U_{drift}^2 + U_{osci}^2 + U_{temp}^2)} \quad \ldots\ldots\ldots\ldots\ldots(1)$$

After applying uncertainty factors, the relative expanded uncertainty (k=2) for NIS 3 kNm torque standard machine is less than 5×10^{-4}.

4. Conclusion

The performance evaluation of NIS new 3 kNm reference torque standard machine shows that, the relative expanded uncertainty obtained is 5×10^{-4}, which is acceptable value compared with other standard machines. Bilateral comparison with leading institute up to 3 kNm was planned.

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