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THAILAND TORQUE WITH CROSS FORCE COMPARISON

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Abstract: This paper presents the results of an inter-laboratory comparison in torque with cross force measurement among fifteen participating laboratories in Thailand. This is the first time for setting torque type inter-laboratory comparison. The comparison was carried out between July 12th, 2010 and November 5th, 2010. The program was piloted and referenced by the National Institute of Metrology (Thailand), NIMT.

The comparison was made as a star form, in which the artifacts were sent back to the pilot laboratory (to measure) after every measurement conducted by the participating laboratories. This pattern continued until all participating laboratories completed their measurement. The reference value, which was used to compare the results from the pilot laboratory and that from the participating laboratories, was specifically provided for each participating laboratory. After the pilot laboratory measured the artifacts to find out the reference value for the next participating laboratory, the artifacts were sent to that participating laboratory.

The degrees of equivalence of each laboratory's competence were expressed by E_n numbers. The results of this comparison showed that the deviation from the reference value was almost within ± 1.5 percent and $E_n \leq 1$. In the metrology investigation, the influence of reproducibility from re-setting torque value could be estimated about ± 0.5 percent of reading.

Keywords: Torque, inter-comparison.

1. INTRODUCTION

Previously, the torque club, one of the metrological clubs of the National Institute of Metrology (NIMT), organized the inter-laboratory comparison three times, all of which achieved considerable attention and received excellent responses from all participants. Nevertheless, all those comparisons did not include the measurement of torque at the maximum limit of value-setting typed torque tools, despite the fact that this type of torque measurement is a basic measurement applied in calibration of torque equipment in Thailand. Moreover, in conformity assessment of calibration laboratories, all important details that can affect this type of torque measurement must be considered. Therefore, the calibration laboratories that would like to get accredited have to be aware of these important details and perform their measurements correctly.

A protocol of the comparison was prepared by the pilot laboratory and distributed to the participating laboratories on January 26th, 2010. The comments and opinions were revised. All participants accepted and approved the technical protocol no. MT03/2553 [1]. The participating laboratories used torque wrench calibration devices as their standards.

2. ARTIFACT AND MEASUREMENT POINT

The comparison artifacts were chosen from the torque wrench with the specifications that conformed to Type II, class A of ISO 6789: 2003(E) entitled "Assembly tools for screws and nuts-hand torque tools - requirement and test methods for design conformance testing, quality conformance testing and recalibration procedure" [2]. Additionally, the accuracy and precision of the artifacts was greatly taken into consideration. Therefore, the setting torque wrench manufactured by GEDORE model number 8561-01 Dremometer B with the best scale resolution of 5 N·m and the other manufactured by NORBAR TORQUE TOOLS model 330 PTR with the best scale resolution of 5 N·m were selected as the comparison artifacts. Both torque wrenches were capable of working in the clockwise direction. The driving head of each wrench was square in shape and had the size of 0.5 inch × 0.5 inch. The measurements at the nominal setting were valued 20, 40, 60, 80 and 100 N·m and 130, 200, 270 and 330 N·m in the clockwise direction. This range well covers most practical torque measurements in Thailand.

The whole process of comparison took 116 days and the artifacts were placed at least 2 laboratories a week. This should endure the influence quantity of various environmental conditions during handling transportation and measurement. Thus, the stability of the artifacts was monitored before each comparison was conducted as shown in Figure 1(a) and 1(b).

Overall, it was found that the whole range of measurement of two artifacts was the long term stability at ± 0.50 %. For this comparison, the artifacts were repeatedly measured by the pilot laboratory after they were measured by each participant laboratory before forwarding them to the next scheduled laboratory within 3 days. When the time was considered, the average stability of the artifact was ± 0.25 %, and it was acceptable due to the calibration and measurement capability of participants, which was not better than or equal to ± 1.0 %.

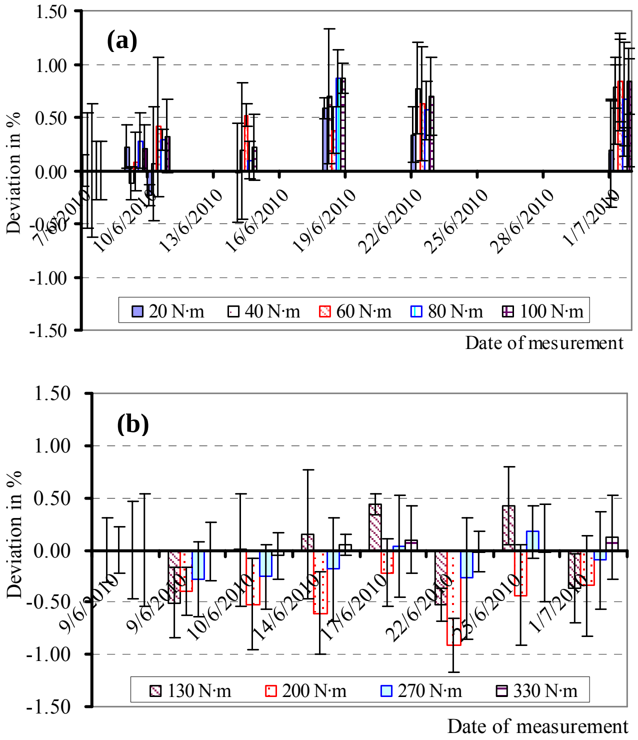


Figure 1: The long term stability of (a) GEDORE Drehmometer B and (b) NORBAR 330 PTR

3. PRE-INVESTIGATION

To prevent an undesirable quantity, the pilot laboratory pre-investigated important issues that significantly affected the results of torque measurements of this type: (1) the measurement sequence, (2) time period for loading from 80 % to the final target value, (3) setting torque value method, and (4) ball position of driving square.

3.1 MEASUREMENT SEQUENCE

The deviation of the measurement sequence from the one stated within this procedure affected the measurement results significantly. Figure 2(a) shows the characteristics of measured values obtained from the typical procedure, which was applied in this protocol (preload at 100 N·m, then measurements at 20, 60 and 100 N·m, respectively). The deviation value from the measurement group was the first value of all measurement points. This phenomenon might occur because of internal mechanical viscosity since not all the points of measurements were preloaded. These deviations had significant values compared to the acceptance criteria in ISO 6789: 2003 (E).

Figure 2(b) shows the characteristics of measured values obtained from a different procedure (preload at 100, then measurements at 100, 60 and 20 N·m, respectively). At 20 N·m and 60 N·m, the first measured values significantly deviated from the other measured values at the same measurement point. However, at 100 N·m, the first measured value did not significantly deviate from the other measured values. This was because the measurements at 100 N·m were consequently performed after the preloading process, resulting in more mechanical stabilization of the torque wrench. At 20 N·m and 60 N·m, the deviations of the first measured value was significant due to the internal mechanical viscosity as in the case of the typical procedure.

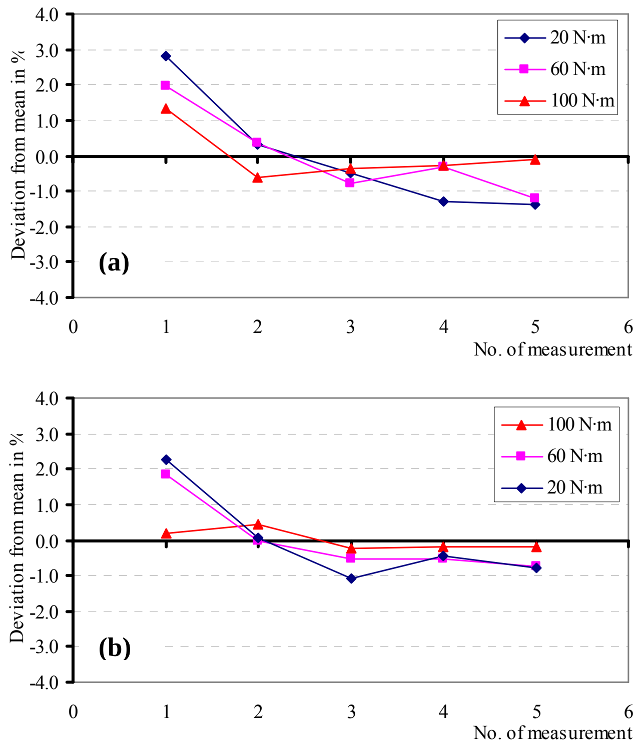


Figure 2: The deviation from mean of the measurement (a) by typical procedure and (b) by difference procedure

3.2 LOADING TIME PERIOD

This protocol specifies that the appropriate time period for loading at the final stage is from 0.5 s to 4 s, according to ISO 6789: 2003 (E).

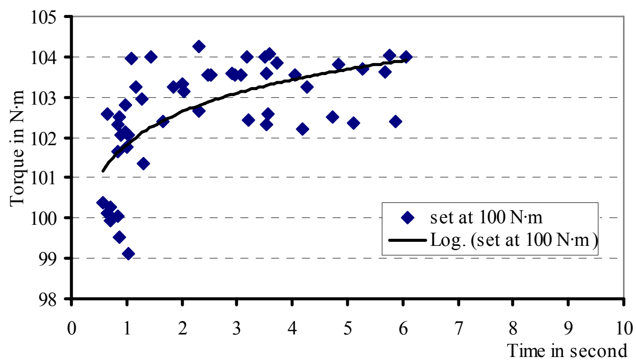


Figure 3: Characteristics of distribution of the time period of measurement

Figure 3 shows the distribution of the measured torque values at 100 N·m torque setting as a function of the loading time spent in the final stage (from 0.5 s to 6 s). For the period of less than 1 s, the values were badly scattered, yielding poor repeatability and unreliable measurement results. However, when the time period was expanded, the agreement of the repeatedly measured values was greatly improved. The poor precision at the shorter loading time occurred due to the limiting capabilities of the standard equipments such as sampling rates or the inappropriate filter settings. Therefore, all the participants were advised to be aware of the existent of this effect.

3.3 METHOD OF SETTING TORQUE VALUE

The assumption of torque measurement errors caused by setting torque values was not caused by only the readability but also the setting method of each operator, such as the directions of adjustment (from a low to high value or vice versa), the movement or disturbance after the button is locked, and the adjustment speed. As a result, this behavior, which is shown in Figure 4(a), affected the mechanism of the setting torque wrench.

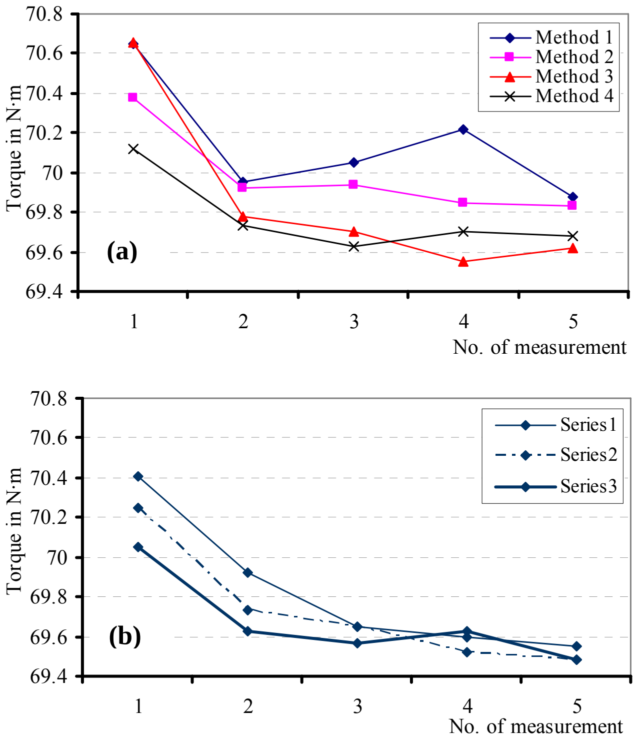


Figure 4: The deviation of measurement due to the (a) readability and difference method of setting torque value and (b) readability and same method of setting torque value

Figure 4(b) shows the measurement result of the same method of setting torque value (from minimum scale to target torque value) in a 3 measurement series. However, the effect would be more or less depending on the quality and design of the torque wrench and the behavior of the individual operators of the torque value setting.

3.4 EFFECT OF BALL POSITION

The ball position of driving square was another important influence that can cause an eccentric shift. The relative deviations of the measurement occurred due to a geometrical alteration of the effective torque transmitted from the torque wrench calibrator to the torque wrench [3]. The eccentric driving square shifted the centre of the wrench from centre of torque wrench calibrator by distance of ball curve (Δx). The effective length of the lever was changed by the projection of Δx on original.

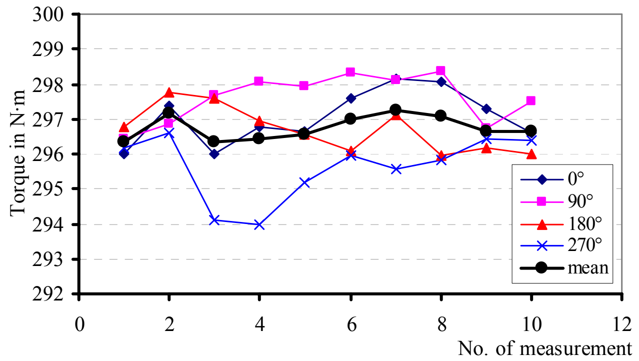


Figure 5: The deviation of measurement due to ball position on driving square

Figure 5 shows the distribution of 10 measurement values of each ball position. The measurement value of 90° ball position is more than the value of 0° and 180° ball position and the measurements value from 270° ball position are lowest. Therefore, this comparison specifies that the appropriate ball position at 0° as shown in figure 6.

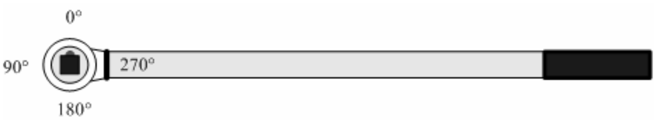


Figure 6: The ball position of driving square of the wrench

The pre-investigation results show that all of influence quantities significantly affected the results of measurements. Therefore, the participants were requested to strictly follow the procedures laid down in the protocol, otherwise the results might not be metrologically comparable.

4. CHRONOLOGY OF MEASUREMENT AND TRANSPORTATION

The artifacts were circulated to all participants between July 12th, 2010 and November 5th, 2010. The pilot laboratory first carried out the measurement and conducted it every time after the artifacts returned from each participant. For each circulation, the staff of each participating laboratory responded to the transport individually. The participants had to check the arrival of artifacts according to the technical protocol before and after making measurement. The actual timetable and results of comparison were submitted to the pilot laboratory by the participants. Then, the measurement results of each participating laboratory were analyzed for the deviation and degrees of equivalence in final report [4].

5. MEASUREMENT

5.1 PREPARATION AND MEASUREMENT SETUP

The environmental condition of measurement performed at the temperature of (22 ± 1) °C and at the relative humidity of (50 ± 10) %. The ambient temperature and relative humidity surrounding the comparison artifacts was recorded and reported. The torque standard was turned on and left at least 2 hours to achieve equilibrium with the laboratory's atmospheric condition, especially the thermal equilibrium, before any measurement started. The connecting surface between the artifacts and the standard must be clean and totally dust-free. The position of the driving square head was fixed at 0° throughout the measurement process.

The standard device and the artifacts were set and oriented in either a vertical or horizontal position. The operating force was applied within the ± 10° angular limits, at the centre of the hand-hold position of the grip or the marked loading point.

5.2 MEASUREMENT PROCEDURE

The comparison of each artifact was measured at (20, 40, 60, 80, 100) N·m (for 8561-01 Dremometer B) and (130, 200, 270, 330) N·m (for 330 PTR) in the clockwise operating direction. The number of measurement at each setting and loading time period is shown in Figure 7.

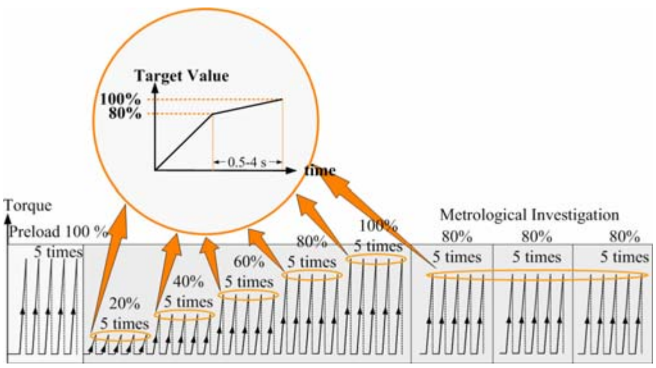


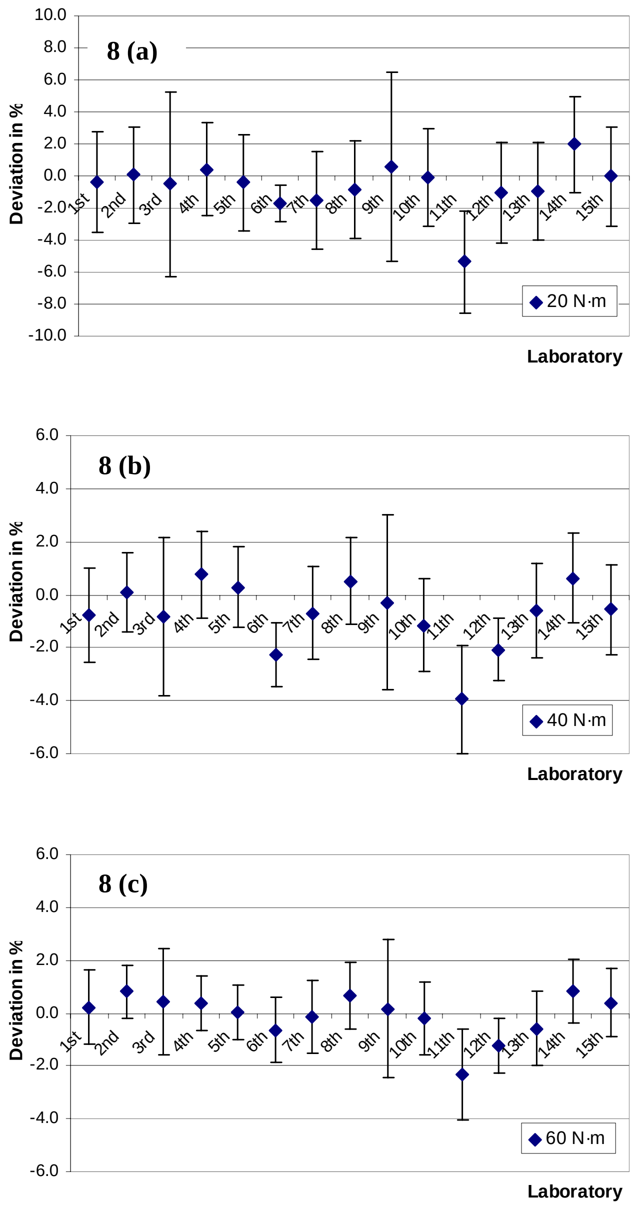
Figure 7: The measurement process

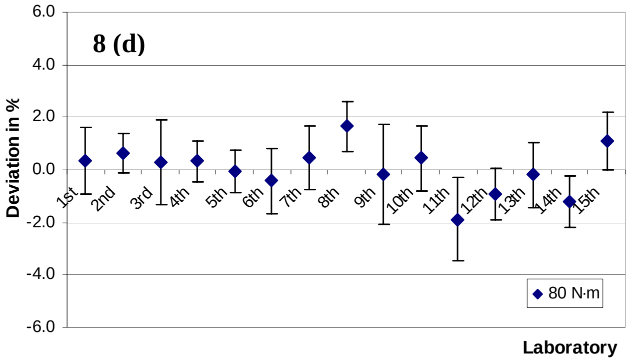
The pilot laboratory was also interested in the deviation caused by setting up of the torque wrench type. This deviation was associated with the readability while setting up each operator. Another influence that affected the deviation of the setting torque wrench setup was the stroke of adjustment. In order to prove such doubt, in this comparison, each participating laboratory was assigned to continue the measurement from the normal comparison procedure, following the pattern of 5 times a set at 80 N·m for 8561-01 Dremometer B and 270 N·m for 330 PTR with 3 sets of data as shown in Figure 7.

6. RESULTS OF THE MEASUREMENT

6.1 COMPARISON RESULTS

All participants submitted the measurement results and expanded uncertainty as well as uncertainty budgets based on the technical protocol. The evaluation of measurement results were calculated according to ISO/IEC GUIDE 43-1: 1997 and ISO/IEC GUIDE 43-2: 1997 "Proficiency Testing by the Interlaboratory Comparisons" [5, 6]. Figures 8 to 9 show the resulting deviations from these reference values and their uncertainties.





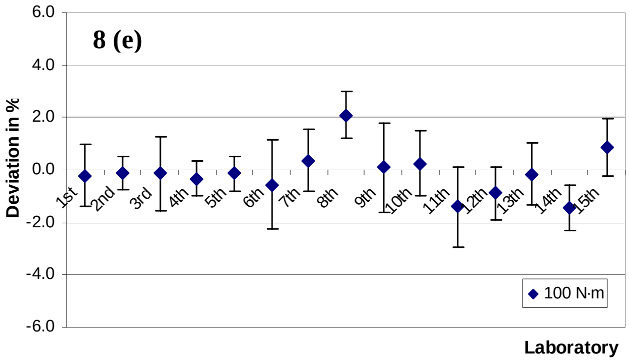
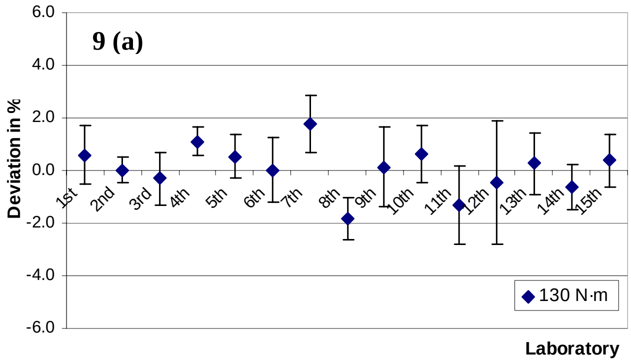
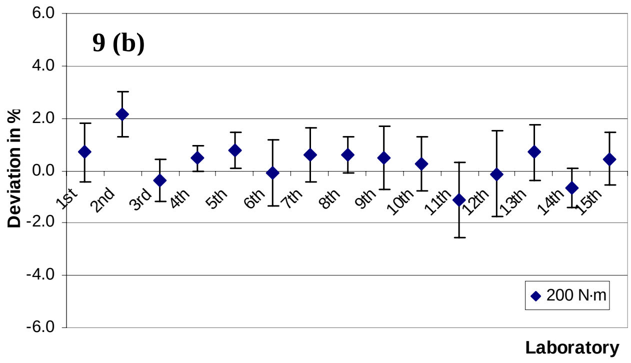
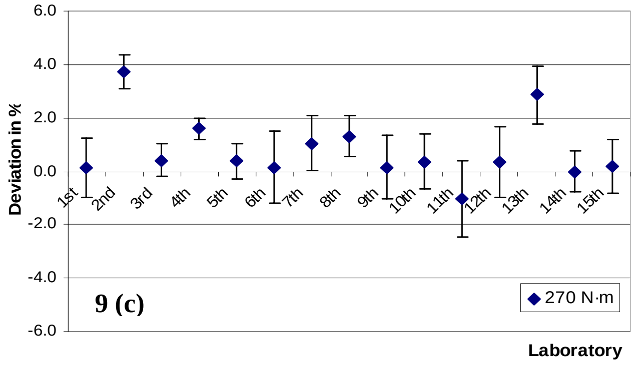


Figure 8: Relative deviations of the measurement results from reference value for 8561-01 Dremometer B at (a) 20 N·m (b) 40 N·m (c) 60 N·m (d) 80 N·m and (e) 100 N·m clockwise torque and relative expanded (*k*=2) uncertainties.







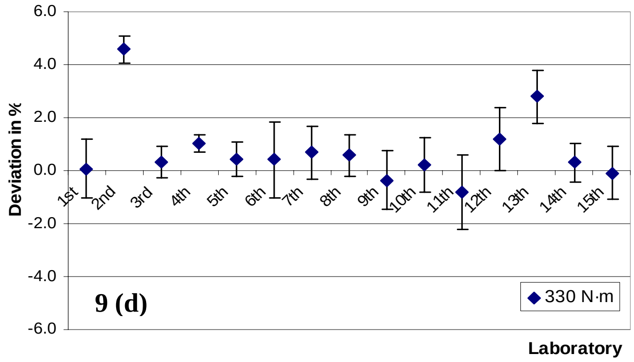
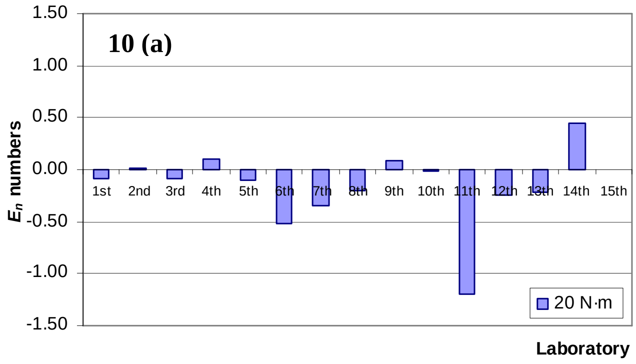


Figure 9: Relative deviations of the measurement results from reference value for 330 PTR at (a) 130 N·m (b) 200 N·m (c) 270 N·m (d) and (e) 330 N·m clockwise torque and relative expanded (*k*=2) uncertainties.

The degree of equivalence (E_n) between measurement values of the participants and the comparison reference values were calculated according to ISO/IEC GUIDE 43-1: 1997 and ISO/IEC GUIDE 43-2: 1997. Figures 10 to 11 show the results.



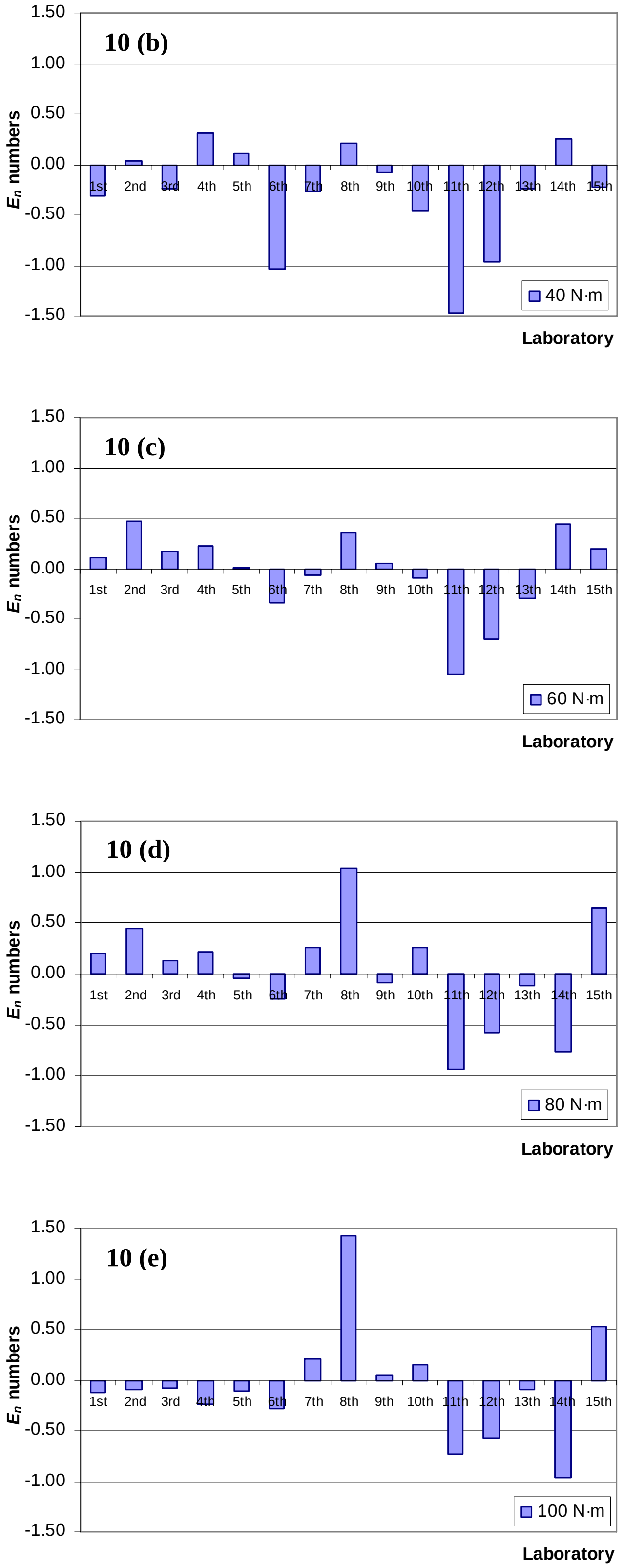


Figure 10: Degree of equivalence for all measurements made by the participating laboratories with 8561-01 Dremometer B at (a) 20 N·m (b) 40 N·m (c) 60 N·m (d) 80 N·m and (e) 100 N·m clockwise torque.

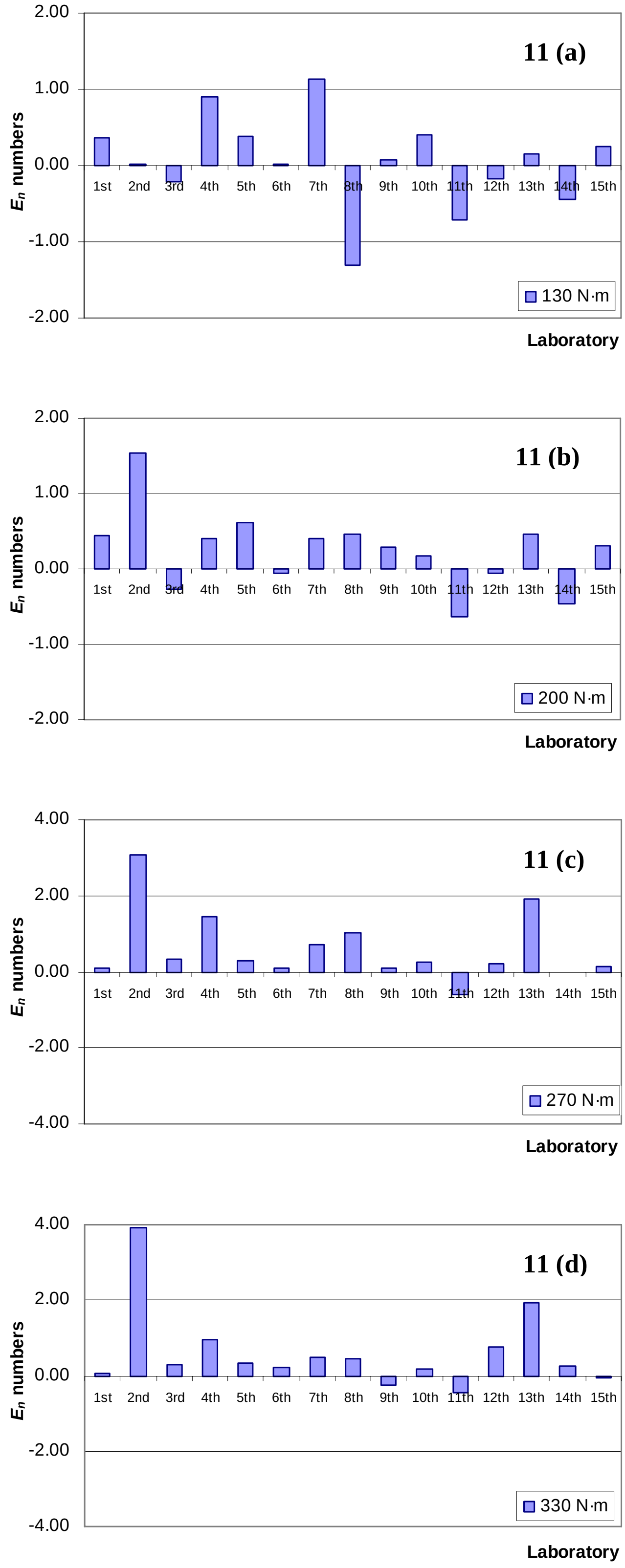


Figure 11: Degree of equivalence for all measurements made by the participating laboratories with 330 TPR at (a) 130 N·m (b) 200 N·m (c) 270 N·m and (d) 330 N·m clockwise torque.

6.2 RESULTS OF INVESTIGATION

This begins with an analysis of the pilot laboratory's measurement data at 80 N·m, 3 series and 5 times per series (Figure 12). The first data set was a measurement result from the setting torque valued from 20 N·m to 80 N·m measurement point. The second data set was a measurement result from the setting torque valued from 40 N·m to 80 N·m measurement point. The third data set was a measurement result from the setting torque valued from 60 N·m to 80 N·m measurement point. The measurement results showed the distribution ± 0.55 %, ± 0.37 % and ± 0.14 % of data set 1, set 2, and set 3, respectively. The measurement results from a narrow stroke of adjustment gave the distribution of data less than the measurement results from a wide stroke of adjustment.

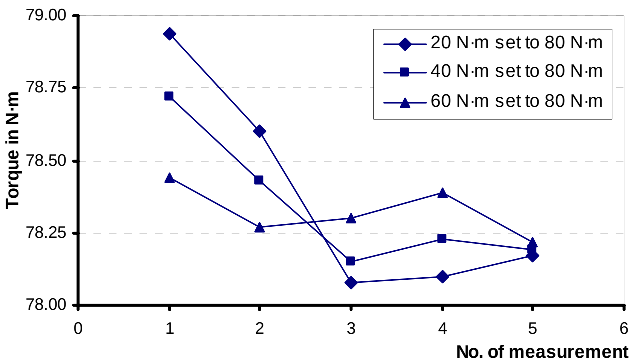


Figure 12: Distribution of measurement in each stroke of 8561-01 Dremometer B at 80 N·m clockwise torque

The stroke of adjustment not only affected the readability of measurement but also affected to the mean value. Almost the measurement results of the 3 set measurement series of 15 participating laboratories were in the same range, with the deviation about ± 0.25 %. However, the mean value of 3 set measurement data deviated from the mean of typical measurement value about ± 0.50 %.

7. DISCUSSION AND CONCLUSION

Fifteen calibration laboratories in Thailand participated in this interlaboratory comparison of torque with cross force from 20 N·m to 330 N·m clockwise direction. Two specially verified setting torque wrenches were circulated as the artifacts for the whole comparison. From the verifying results, the behavior of the artifacts was well characterized and it was confirmed that capabilities of the artifacts to achieve this comparison were sufficient. In order to ensure the reliability of the artifacts, the artifacts were sent back to the pilot laboratory in order to be measured every 3 day during the comparison was carried out.

The participants' competence was determined and was expressed quantitatively by two rules: (1) the deviation from the reference values and (2) the E_n numbers. Nine participating laboratories had a comparison result of all the measurement points that were subject to confirm the uncertainty of measurement and the E_n number was less than 1, accounting for 60 % of participating laboratories. Three participating laboratories had a comparison result of the only one measurement point of E_n number over than 1 and accounted for 20 %. Other three participating laboratories had a comparison result of three measurement points of E_n number over than 1 and accounted for 20 %. When considering each of the measurement points, it showed that among all the measurement points, only one participating laboratory had E_n numbers more than 1, except for the measurement point at 40 N·m, 130 N·m and 330 N·m, the E_n numbers were more than 1 for 2 laboratories. Overall, the results of this comparison were satisfactory.

From the metrology investigation, it showed that the stroke of adjustment of settings torque wrench also affected the deviation of these comparison results. If the participants did not follow the sequence of required measurement, the measured value might be associated with the influence of this setting behavior ± 0.50 %. It might also be the repeatability of measurement, which was more than its actuality. Another factor that affected the E_n number more than 1 was an uncertainty of the measurement of the standard used in the unreasonable comparison. Therefore, any laboratories that had a result of comparison, E_n number closed to or more than 1, should be determined the cause of the deviation and be made correction immediately.

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