Influence of Rotational Mounting Conditions on Calibration Results and those Uncertainties in Reference Torque Wrenches

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Abstract. In the calibration of reference torque wrenches, the influence of various calibration conditions on the calibration results and those uncertainties should be considered for the precise measurement such as less than 0.1 % of relative expanded uncertainty level. In this research, the differences of changing way of rotational mounting positions were examined, where the changing ways by (a) changing the position of sensing element itself (with lever position), (b) changing the position of a detachable square drive apart from the sensing element (main body) and (c) changing the position of sensing element together with the male square drive apart from the female square hole installed in the measuring side of the torque calibration equipment, were compared by using a reference torque wrench (RTW) of rated capacity of 1 kN-m. Unexpectedly, severe differences did not appear depending on those calibration conditions, differing from the case of RTWs of smaller rated capacities.

1. Introduction

Reference torque wrenches (RTWs, or torque transfer wrenches) are recently becoming used for the calibration of torque wrench calibration devices (or torque wrench testers and/or checkers (TWTs and/or TWCs)) as effective reference standards [1-3]. National Metrology Institute of Japan (NMIJ) has promoted the calibration method using RTWs, too [4]. The author has also investigated the differences of calibration results of RTWs in the case using deadweight type torque standard machines, depending on the changing way of the rotational mounting position for torque-wrench-form transducers, by changing the position of sensing element itself (lever direction itself) (called “Lever way” as shown in figure 1) and by changing the position of a detachable square drive (sq. dr.) (called “Square way” as shown in figure 2) [5]. RTWs with rated capacity of 50 N-m, 100 N-m and 500 N-m were used for the experiment. It was concluded that other additional uncertainties should be considered for the Square way or the changing way should be described in the calibration certificate as one of calibration conditions.

In the Lever way, a counter balance weight is required to be attached on the torque transducer in order to cancel the torque generated by transducer’s weight itself in the case of changing rotational mounting position by changing the angle of the sensing element (by pitch of 120°) with the lever position when the deadweight type torque calibration equipment having horizontal measurement axis is used for
the calibration. An example of counter plates and weights with a transducer is shown in figure 3. The illustration of Lever way for clockwise and counterclockwise torques (CW and CCW) is shown in figure 4. In figure 4, four-colored squares indicate close-up actual directions of the sq.dr. fixed on the main body of the transducer. The mounting position of the transducer is changed together with “square hole (sq. ho.) adapter shaft (figure 5)” fixed by a block in the measuring side. Therefore, this changing way of mounting position is quite similar to that of “pure torque loading” with the round shaft ended transducer.

In the Square way, the detachable sq. dr. is changed its position by pitch of 90° apart from the sensing element (main body) of the transducer. An example of sq. dr. with the torque-wrench-form transducer is shown in figure 6. The illustration of Square way for CW and CCW torques is shown in figure 7. Although the Square way could not be said the real changing way of the rotational mounting position, it could be said that an aspect of surface contact between male sq. dr. and female sq. ho. is changed every mounting position. Such a surface contact change happens in the general use of “Hand torque wrenches.”
So, the author tried to change the mounting position with changing the sq. dr. together with the main body (not apart from each other) and with changing the contact aspect between the sq. dr. and the sq. ho., by pitch of 90°, then compared with the Lever way and Square way. This changing way is called “Face way.” The illustration of Face way for CW and CCW torques is shown in figure 8.

2. Experimental conditions

2.1. Experimental devices

A torque-wrench-form transducer TTS/1000Nm (rated capacity of 1 kN·m) with an indicator/amplifier DMP40S2 was used for this experiment as the typical large capacity RTW. A deadweight type torque standard machine with rated capacity of 1 kN·m (so called 1-kN-m-DWTSM) was used for this calibration experiment.

2.2. Experimental procedures

The calibration was conducted according to JMIF016 [6], a guideline for calibration laboratories of reference torque wrenches, issued by Japan Measurement Instrumentation Federation. The procedure of this guideline is similar to those of guidelines issued in other countries/economies except the changing way of mounting position.

Two increasing and decreasing calibration cycles were conducted after three times pre-loadings up to 100 % of the maximum torque at the 0° position. After changing mounting position, one increasing and
decreasing calibration cycle was performed after one pre-loading. The calibration series was repeated at the third rotational position. Then, at the same position, the calibration series was repeated changing the lever length from the average length to the minimum one. The torque steps were eight steps ($10\%$, $20\%$, $30\%$, $40\%$, $50\%$, $60\%$, $80\%$ and $100\%$ of the maximum torque).

3. Results and discussion

Experimental results are shown in figure 9(a) for the relative deviations of calibration results for the Square way and the Face way from the Lever way, and in figure 9(b) for the relative expanded uncertainties in three changing ways. The relative deviations were from less than $1.0\times10^{-5}$ to $1.6\times10^{-4}$, whereas the relative uncertainties were from $2.6\times10^{-4}$ to $4.6\times10^{-4}$.

4. Conclusion

In the calibration of the reference torque wrench in large capacity of 1 kN∙m, severe differences did not appear depending on the above calibration conditions, differing from the case of RTWs of rated capacities from 50 N∙m to 500 N∙m (the relative deviations were from $3.5\times10^{-4}$ to $1.4\times10^{-3}$, whereas the relative uncertainties were from $8.2\times10^{-5}$ to $5.8\times10^{-4}$) \cite{5}.

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