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# Development of a Portable Torque Wrench Tester

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# Development of a Portable Torque Wrench Tester

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**Abstract.** A portable torque wrench tester (PTWT) with calibration range from 0.5 Nm to 60 Nm has been developed and evaluated for periodic or on-site calibration of setting type torque wrenches, indicating type torque wrenches and hand torque screwdrivers. The PTWT is easy to carry with weight about 10 kg, simple and efficient operation and energy saving with an automatic loading and calibrating system. The relative expanded uncertainty of torque realized by the PTWT was estimated to be 0.8%, with the coverage factor $k$=2. A comparison experiment has been done between the PTWT and a reference torque standard at our laboratory. The consistency between these two devices under the claimed uncertainties was verified.

## 1. Introduction

Hand torque wrenches are necessary for assembling in various fields, such as automotive, ship-building, aerospace, power and other industries. The quality of assembling procedure is highly dependent on the accurate torque control. Accurate and reliable measurement of the torque value will help to improve and enhance product performance. In most cases, it is assumed that a torque wrench will deliver the requested torque value if set correctly. However, torque wrenches have moving parts that will be subject to wear. They are also subject to harsh operating conditions in the field, which elevates the risk of damage [1]. In order to maintain consistent accuracy, calibration or verification of torque wrenches or screwdrivers on a periodic basis would be advisable. However, this is only part of the requirement. Data obtained from the calibration of hundreds of wrenches over several year period indicates that there is still a big probability that wrench failure occurs prior to recalibration periodically, especially those overused. Those disqualified wrenches may cause bolting related failure till recalibration. Consequently, it is reasonable that wrenches themselves need to be on-site verified on a moveable torque wrench tester (TWT) just before assembling. There are many commercial TWTs available for hand torque tools, most of which are designed only for laboratorial conditions. That heavy laboratorial equipment with poor mobility are inconvenient for on-site calibration. Therefore, we developed a portable torque wrench tester (PTWT) for on-site calibration or verification of several commonly used hand torque tools, namely, setting type torque wrenches (STWs), indicating type torque wrenches (ITWs) and hand torque screwdrivers (HTSs). The relative expanded uncertainty of torque realized by the PTWT was evaluated in the 0.5~60 Nm torque range and was estimated to be 0.8%, with a coverage factor, $k$, being equal to 2. The PTWT was compared with a reference torque standard (RTS) at our lab. The calibration results obtained by these two devices were coincided within the claimed uncertainties.

## 2. Establishment of equipment

### *2.1. Equipments*

Light in weight, easy to operate and automatic procedure was what we pursue with this equipment. Two easily detachable torque transducers were adopted to cover the target range from 0.5 Nm to 60 Nm. A servo motor in combine with a planet gear was applied to realize automatic calibration procedure and output a rated capacity of 60 Nm, which free our hands and conserve time. In the design process of the mechanical structure, finite element calculations had been carried out to optimize the clamping structure geometry with the aim to guarantee strength and reliability.

A schematic of the PTWT is shown in figure 1. The main components were installed onto a framework assembled of aluminium profile. A handle on the top and castors with brakes at four corners makes it much easier to move. Motor, planet gear, torque transducer and torsion axis of wrench were connected along the measurement axis. Various square drives were prepared in different sizes to enable torque wrenches of various sizes and shapes to be installed on either of the two torque transducers.

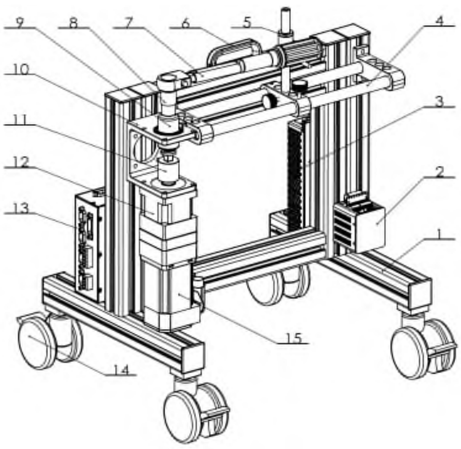


**Figure 1.** Schematic of the PTWT.

1. Profile; 2. Driver; 3. Power supply; 4. Guiders; 5. Rod for loading point; 6. Handle; 7. Torque wrench; 8. Square drive; 9. Torque transducer; 10. Holder; 11. Adapter; 12. Planet gear; 13. PLC device; 14. Castor with brake; 15. Motor.

### *2.2. Calibration procedures*

A PLC device is used to control the movements of the motor and run a calibration procedure via a PC that acts as man-machine interface. Due to diversity of principles and structures, we designed different calibration procedures for each type of wrenches as illustrated in figure 2, in which, ‘setting mode’ is for STWs, ‘indicating mode’ for ITWs (includes digital type and analogue type) and ‘manual mode’ for HTSs or other torque tools need to be manually calibrated. The machine can operate almost fully automatically with the exception that, manual mode being selected, or installing and uninstalling a wrench whenever required, or exchanging a torque transducer during the measurement process.

*2.2.1. Setting mode.* Internal structure of a STW is a combination of leveraged structure and spring. Once the applied torque is large enough to overcome resistance produced by the internal spring, protuberant node of the lever will strike inner wall of the wrench immediately, thus makes a ‘click’ sound and torque released. Calibration of a STW is the measurement of the peak torque just before releasing to a known torque standard such as a TWT and adjustment to within specific tolerances if necessary. The aim of developing an automatic procedure is to improve efficiency in contrast to the conventional manual procedure. Thus, the loading and unloading process should be as fast as possible. However, loading too fast upon peak point may lead to overloading and thus in return do great damage to the tested wrench. Consequently, a tested wrench is first loaded to 80% of the target torque at a high speed according to JJF 707 [2]. Then, decrease loading speed gradually, and activate peak torque identification simultaneously. Once a peak is detected, note the peak value and unload quickly. Otherwise, continue to load and identify. Note that all the calibration procedure is done automatically by a calibration program implanted in the PLC device in figure 1. The calibration program would remind you to unmount the tested STW to preset the next target torque after all the repetitive tests of one test point is done.

*2.2.2. Indicating mode.* Calibration procedure of ITWs is almost the same as that of STWs before 80% of the loading process, as shown in figure 2b. Instead of peak identification, a tested ITW would be gradually loaded to the target torque and maintained for a few seconds to note the reading of the ITW. Afterwards, load to the next point till 100% of torque range is done. Repeat the above steps till test times is enough.

*2.2.3. Manual mode.* Figure 2c presents calibration procedure of HTSs or other torque tools need to be manually calibrated. Before starting a calibration procedure, set display mode of the tested torque tool to peak mode instead of track mode if the tested tool is an indication one. First, brake the motor axis to prevent the torque transducer from rotating. And then, manually apply load to the torque transducer through the tested torque tool. Activate peak torque identification once the applied load reaches 80% of the target torque. Note reading of the tested tool and unload when a torque peak is identified. Stop the calibration procedure when test times are enough, otherwise move to the next step.

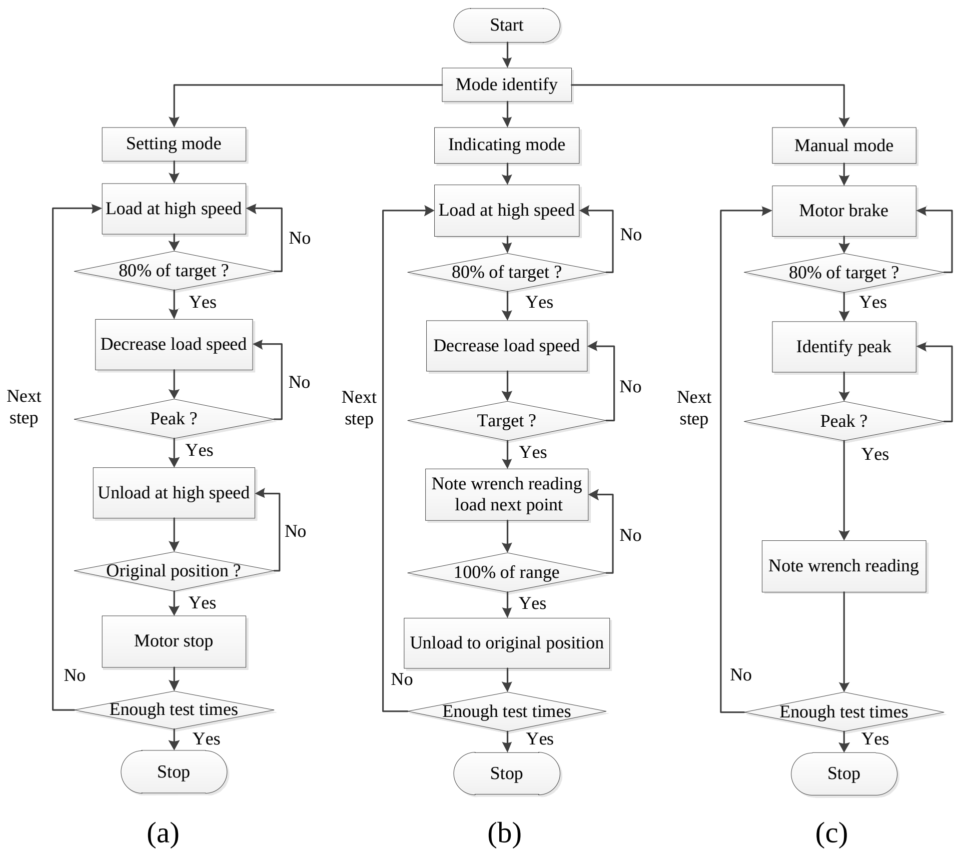


**Figure 2.** Calibration procedure.

a. Setting mode; b. Indicating mode; c. Manual mode.

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## 3. Uncertainty evaluation

### *3.1. Uncertainty of the calibration results*

The characteristics of the new PTWT were evaluated according to GJB 2749A [3] whereas uncertainty of calibration was evaluated according to ISO/IEC guide 98-3 [4], and evaluation methods are described as following. The relative expanded uncertainty $U_r$ of calibration results for every measuring point is expressed by the following equation:

$$U_r = k \cdot u_c = k \cdot (u_{pro}^2 + u_{rep}^2 + u_{ind}^2 + u_{sta}^2 + u_{res}^2)^{1/2} \quad (1)$$

where $u_c$ is the relative combined standard uncertainty of calibration. $k$ is the coverage factor and $k = 2$ was used in calculation of all expanded uncertainties in this paper, which correspond to the level of confidence of approximate 95 %. $u_{pro}$ is the uncertainty contribution for the reproducibility with a change in the mounting position, $u_{rep}$ is that for the repeatability without a change in the mounting position, $u_{ind}$ is uncertainty due to indication difference from the reference value, $u_{sta}$ is uncertainty due to long stability of transducer sensitivity, $u_{res}$ is that due to the resolution.

### *3.2. Reproducibility with changing mounting position*

In consideration of the influence of mounting position on the calibration results, Reproducibility with changing mounting position $u_{pro}$ was evaluated by a certain number of repeated tests in a way that after each test, the wrench and rod for loading point were reinstalled and square drive and torque transducer were rotated to a different position. The relative reproducibility with different mounting positions is calculated according to (2) as the experimental standard deviation for the measurement values of each mounting position:

$$u_{pro} = \frac{1}{\overline{S_j}} \left( \frac{\sum_{j=1}^{k} \left( S_j - \overline{S_j} \right)^2}{k-1} \right)^{1/2} \quad (2)$$

where, j and $k$ are the indexes of different mounting position and the total number of mounting positions (here $k$=10), respectively. $S_j$ is the measurement value obtained from each mounting position and $\overline{S_j}$ is the mean of $S_j$.

### *3.3. Repeatability in the same mounting position*

The repeatability with the unchanged mounting position $u_{rep}$ was evaluated by certain number of repeated tests with the wrench, rod for loading point, square drive and torque transducer in the same mounting position. The relative repeatability with the unchanged mounting position is calculated as:

$$u_{rep} = \frac{1}{\overline{S_i}} \left( \frac{\sum_{i=1}^{n} \left( S_i - \overline{S_i} \right)^2}{n-1} \right)^{1/2} \quad (3)$$

where, i and $n$ are the indexes of cycles and the total number of cycles (here $n$=10), respectively. $S_j$ is the measurement value obtained from each cycle and $\overline{S_i}$ is the mean of $S_i$.

### *3.4. Deviation due to indication*

The relative deviation due to the indication $u_{ind}$ is calculated as the difference between reference values indicated by a reference torque wrench or a weight-bar-system of higher grade and the indicating results of PTWT.

### *3.5. Stability*

The PTWT was calibrated four times by using a torque standard of higher grade over approximately one year in order to investigate its long-term stability. Relative standard uncertainty due to stability $u_{sta}$ is calculated as:

$$u_{\rm sta} = \frac{S_{\rm max} - S_{\rm min}}{d_{\rm m} S_{\rm mean}} \tag{4}$$

where, $S_{max}$, $S_{min}$ and $S_{mean}$ are the maximum, minimum and mean of the 4 calibration results, respectively. Here, $d_m$ equals to 2.06 ascribed to 4 calibration results [3].

### *3.6. Resolution*

The resolution $r$ of the indication is defined as the smallest fraction of a scale division that is readable in the case of analogue scale. In the case of digital scale, $r$ is considered to be one increment of the last active number of the numerical indicator, provided that the indication does not fluctuate when the PTWT is under the non-loading condition. Relative standard uncertainty due to resolution $u_{res}$ is calculated according to (5), by determining $r$ as a half-width of the rectangular distribution:

$$u_{\rm res} = \left(\frac{2}{3}\right)^{1/2} \frac{r}{2T_{\rm i}} \tag{5}$$

where, $T_i$ means applied toque. $u_{res}$ is multiplied by $(2)^{1/2}$ considering that the measurement value is obtained as the difference between the indicated values of the loaded torque step and non-loading zero step before starting the cycle (double readings) [5].

### *3.7. Evaluation of $E_n$ number*

Intra-laboratorial comparison was conducted between PTWT and a RTS at our lab using several torque wrenches as transfer devices. The $E_n$ ratio between PTWT and the RTS for each measuring point was evaluated using the following equation:

$$E_{\rm n} = \frac{S_{\rm ptwt} - S_{\rm ref}}{S_{\rm ref}\,(U_{\rm ptwt}^2 + U_{\rm ref}^2)^{1/2}} \tag{6}$$

where, $S_{ptwt}$, $S_{ref}$ denote calibration results of the same point of a transfer device given by PTWT and the RTS, and $U_{ptwt}$, $U_{ref}$ are the associated relative expanded uncertainties.

## 4. Results and discussion

Uncertainty of the calibration results was evaluated at 0.5 Nm, 2 Nm, 5 Nm, 30 Nm and 60 Nm. The relative expanded uncertainty $U_r$ of every point is calculated by (1) and summarized in table 1. In all the evaluated cases, the expanded relative uncertainty of calibration results within 0.8 % could be obtained. Thus, the relative expanded uncertainty of torque realized by the PTWT was estimated to be 0.8% in the range of 0.5Nm to 60Nm, with the coverage factor $k$=2. Figure 3 shows the relationship between the relative standard uncertainties and measuring points. In general, relative standard uncertainties are larger in lower torque cases since it’s harder to yield accurate calibration results when calibrating a small-rated-capacity wrench as compared to a greater one. Reproducibility due to changing mounting position have profound effect on the expanded uncertainty, while uncertainties due to resolution are sufficiently small compared with other factors which can be ignored, especially for larger rated capacity.

Figure 4 summarizes the results of the $E_n$ number evaluation between PTWT and the reference standard. The $E_n$ numbers were all less than one over the calibration range of 0.5 Nm to 60 Nm. The comparison results showed good agreement within the uncertainties in all cases. Thus, the torque realized by the PTWT was shown to be equivalent to that achieved by the reference standard.

**Table 1.** Relative expanded uncertainties.

| Torque | 0.5 Nm | 2 Nm | 5 Nm | 30 Nm | 60 Nm |
|---|---|---|---|---|---|
| $U_r$ | 0.75% | 0.64% | 0.71% | 0.66% | 0.46% |

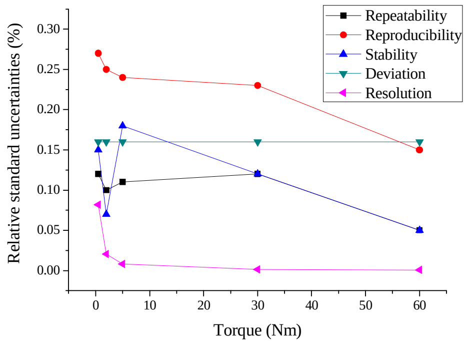


**Figure 3.** Relative standard uncertainties.

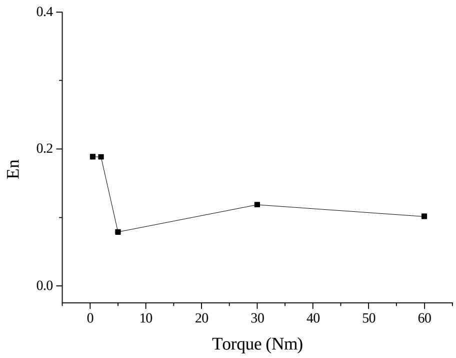


**Figure 4.** Results of $E_n$ evaluation.

## 5. Summary

In this study, a PTWT was developed and evaluated. The relative expanded uncertainty was estimated to be less than 0.8% for the calibration range from 0.5 Nm to 60 Nm, with the coverage factor $k$=2. A comparison has been performed between the PTWT and a RTS machine at our lab. The results of comparison showed quite good agreement within the uncertainties in all cases. Consequently, the consistency between the PTWT and the RTS has been verified under the claimed uncertainties.

## References

[1] Peng Y G and Wang Y 2017 *Appl. Mech. Mater.* **853** 216-20.
[2] JJG 707 2014 *Verification regulation of torque wrenches* (Chinese)
[3] GJB 2749A 2009 *General requirement of establishment and conservation of measurement standard for military metrology* (Chinese)
[4] ISO/IEC guide 98-3 2008 *Uncertainty of measurement-Part 3*
[5] Ogushi K, Nishino A, Maeda K and Ueda K 2011 *Sice Conference* (Tokyo, Japan) pp 411-416.

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