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SUSPENDED-FULCRUM TORQUE STANDARD MACHINE, 2ND REPORT

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Abstract– National Institute of Metrology (Thailand), NIMT has developed the suspended fulcrum torque standard machine. The mainly tasks are metal sheet for fulcrum and hung-weight changing. Moreover propose and investigate methods for the different lever arm length, *Δl* and the sensitivity of fulcrum. Experiment results that using different length of thin sheet metal besides, different evaluation techniques for *Δl* were compared. Sensitivity of fulcrum carried out whole measurement range was discussed. The comparison result between NIMT and PTB was expressed in term of degree of equivalence (E_n). It showed that comparison result was satisfactory.

Keywords: suspended-fulcrum torque standard machine, sensitivity of fulcrum and different lever arm length

1. INTRODUCTION

Authors have designed and constructed a suspended-fulcrum torque standard machine and presented on XIX IMEKO World Congress 2009 [1]. Structure, principle and metrological characteristics evaluation are presented on that conference.

Since many calibration tasks so far, we found that very long thin sheet metal which hung weight causes vibration of weight, unbalance of lever arm length and unstable signal of torque transducer.

Moreover torque transducer setting on torque standard machine was quite inconvenient. It was affected by long thin sheet metal of suspended-fulcrum.

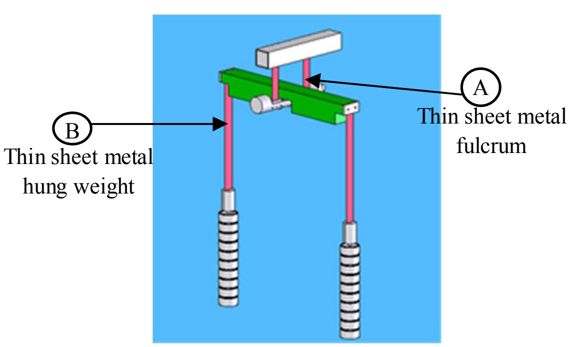


Fig. 1. Schematic of the suspended-fulcrum 10 N·m torque standard machine.

Suspended-fulcrum torque standard machine was moved to a new location on year 2012. In this occasion, short thin sheets were used instated of longer one. Authors have studied operation of the machine after modifying.

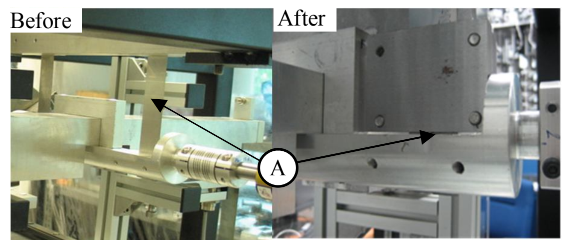


Fig. 2. Show thin sheet metal of suspended-fulcrum (A) before and after modifying.

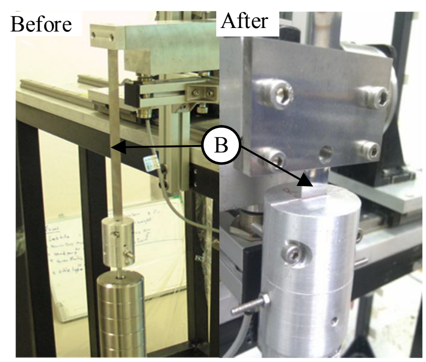


Fig. 3. Show thin sheet metal of hung-weight (B) before and after modifying.

Authors are also interested in finding sensitivity of the machine at every static torque. And finding a different arm length of both sides from two methods, weight balanced technique and torque unbalanced technique. Even torque unbalanced technique has usually applied for torque standard machine (TSM) which air bearing as fulcrum component.

2. EXPERIMENT PLAN

After suspended-fulcrum torque standard machine was moved to a new location, this machine has been modified by replacing with shorted thin sheet metal which hung weight and lever arm.

Regarding to uses original lever arm, it is estimated that over all arm length is unchanged. But reassembly and replacement shorted thin sheet made fulcrum position changed. Thus the different arm length of both sides must be investigated again. In this chance, not only weight balanced technique which was explained in 1st report, but also using torque unbalanced technique will be experimented.

Then, sensitivity of fulcrum is evaluated. The previous report showed sensitivity evaluation at no load only.

This study planed to evaluate sensitivity whole measurement range from no-load up to 10 N·m. And confirm sensitivity every 1 N·m torque applied.

Finally, bilateral comparison with Physikalisch-Technische Bundesanstalt (PTB) was carried out. NIMT computed two sets of measurement results that taken from two values of different arm length evaluations, weight balanced technique and torque unbalanced technique.
They were compared to measurement results of PTB

3. RESULTS AND DISCUSSION

3.1. Difference Arm length of both sides, Δl

3.1.1. Weight balanced technique

Weight balanced technique is torque balancing of both side, clockwise and anticlockwise direction which generated torque by apply weigh. Different arm length of both sides could calculate from different weight applied. Experiment result of *Δl* by using long and short thin sheet of hung weight and suspended fulcrum were compared. It is showed in Fig. 4.

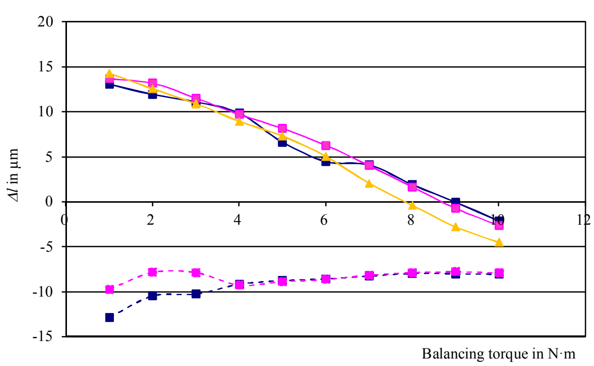


Fig. 4. Different arm length, *Δl* comparing between using short (solid line) and long thin sheet (dash line)

Average of *Δl* from short thin sheet metal is 6 µm whereas average of *Δl* from long thin sheet metal is -8.9 µm as shown in Fig 4. The variation of *Δl* lies down on 14.2 µm to -4.5 µm (0.008%) and -7.8 µm to -12.9 µm (0.005%) for short thin sheet metal and long thin sheet metal respectively.

Δl from long thin sheet metal quite stable when compare to *Δl* from short thin sheet metal. It obviously was decreased corresponding to torque increasing.

From the results, the flexibility of long thin sheet metal is higher than short thin sheet metal. It causes stability of fulcrum position. Therefore, using short thin sheet metal produces more various rang of *Δl* than one although; it was proved lever arm is less swing and easier handle a calibration task. However, the optimized length should be studied.

3.1.2. Torque unbalanced technique

After that, *Δl* is experimented again by using torque unbalanced technique. This technique uses small torque transducer to measure unbalance torque of both sides, clockwise and anticlockwise directions.

Same weight value will apply on both directions. Product of *Δl* and weight will be generated small torque value which measured by torque transducer. *Δl* could calculate from weight applied and torque value.

Experiment result of *Δl* by using torque unbalanced technique which used short thin sheet metal as shown in Fig. 5. It has average value to be 21 µm within variation 25 µm to 14 µm (0.004%).

When comparing to weight balanced technique, found that trend of *Δl* from both techniques is the same. That is, the trend of *Δl* has decreased corresponding to torque increasing. The difference of average from both techniques is 15 µm, (0.006%).

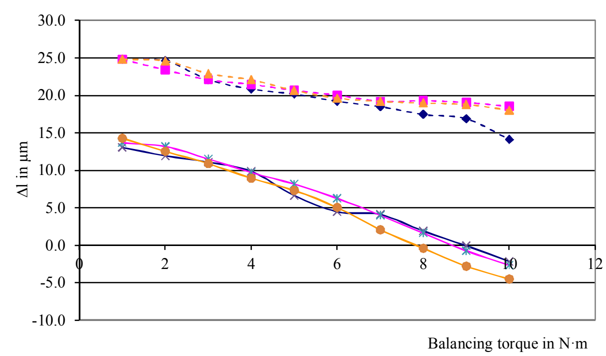


Fig. 5. Different arm length, *Δl* comparing between using weight balance technique (solid line) and torque unbalanced technique (dash line)

The difference of *Δl* might come from influence of misalignment in measurement axis of torque transducer and fulcrum on the actual performance condition. Whereas weight balanced technique is free from any distribution. There is not any misalignment effect. To confirm the difference of *Δl* in both techniques, Torque standard machine (TSM 1 kN·m, Model: Dm-BNME, S/N: 153) is operated to investigate *Δl* in both techniques as shown in Fig. 6.

Second experiment on 1 kN·m TSM showed *Δl* are -26 µm and -18 µm for small torque technique and weight balanced technique respectively. As a result, the difference of torque calculation is 0.002%. These experiment results confirmed both techniques give more different. They should be studied in the future to clarify either one is most precise technique.

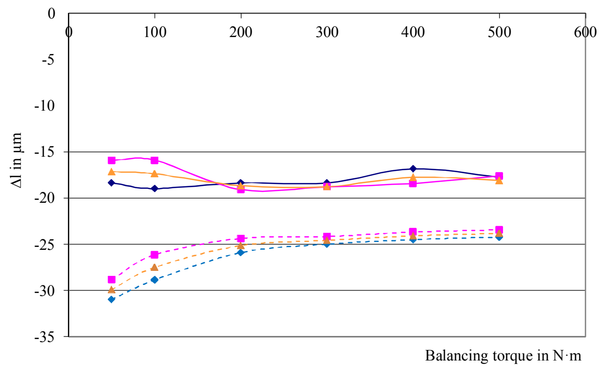
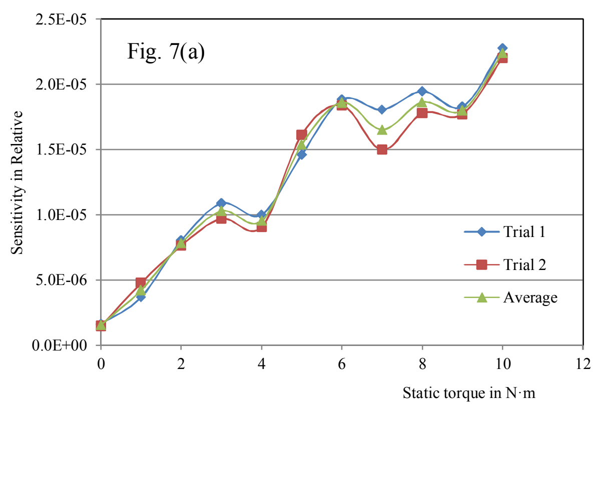


Fig. 6. Different arm length, Δl of 1 kN·m TSM; comparing between using weight balance technique (solid line) and torque unbalanced technique (dash line).

3.2. Sensitivity of Fulcrum, M_{sen}

In Suspended-fulcrum Torque Standard Machine (1st report), bending stiffness of suspended fulcrum is evaluated as representative of sensitivity of fulcrum and calculated only at no-load of lever arm length [3]. However on this report sensitivity of fulcrum is evaluated at static torque not only no-load but also at 1 N·m up to 10 N·m. Bending stiffness of suspended fulcrum at static torque from 0-10 N·m is 0.0005 – 0.01 N·m/° whereas lever arm length is observed in balance condition at acceptance criteria 0° ± 0.0025°.

Thus sensitivity of fulcrum is calculated from bending stiffness above and shown in Fig. 7.



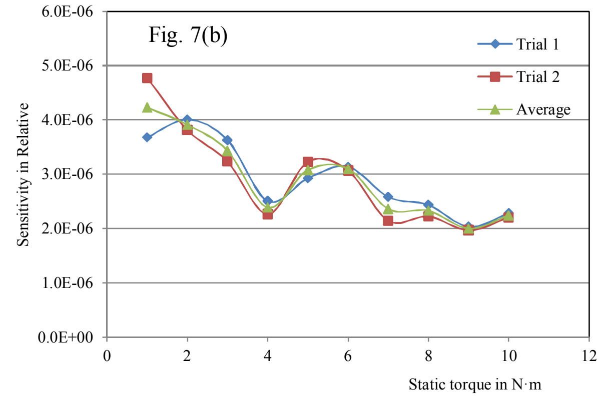


Fig. 7. Sensitivity of fulcrum (a) in N·m and (b) in relative

Sensitivity of fulcrum from TSM at no-load static torque starts from 1.5x 10^{-6} N·m for no-load and increase as direct proportion to static torque until 2.4x 10^{-5} N·m at static torque 10 N·m.

For sensitivity in relative term, it starts from 5x10^{-6} N·m/N·m up to 2x10^{-6} N·m/N·m.

Therefore, it can be explained in formula term as equation (1).

$$M_{sen} = 1.9 \times 10^{-6} T + 3.3 \times 10^{-6} \quad (1)$$

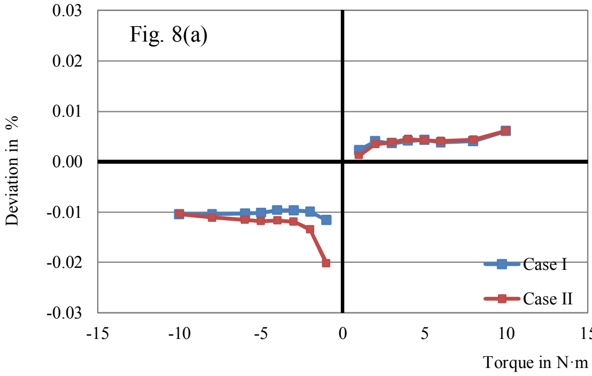
Whereas T is apply torque.

3.3. Comparison results

The comparison between PTB and NIMT on 1 N·m to 10 N·m torque measurement was conducted in order to confirm measurement capabilities of NIMT. It was requires by quality system ISO/IEC 17025 assessment which performed on January 23, 2015. And DIN 51039-2005-12 [4] use as comparison procedure.

A torque transducer capacity 10 N·m, Model: TT1/10N·m, S/N: 36834-02 was used as artifact. NMIs have declared calibration and measurement capabilities (CMC) ± 0.010% and ± 0.002% of NIMT and PTB, respectively. There were 2 sets of NIMT's measurement results that calculate from Δl which evaluated by using two methods, weight balanced technique and torque unbalanced technique. E_n ratio was used to explain degrees of equivalence. Then degrees of equivalence were calculated as shown in Fig. 8.

When using Δl which evaluated by using weight balanced technique, there were deviation between PTB and NIMT measurement within 0.006% to -0.020% with E_n ration with in 0.41 to 0.02 as shown in Fig. 8. There confirmed NIMT's CMC declaration and they were satisfactory.



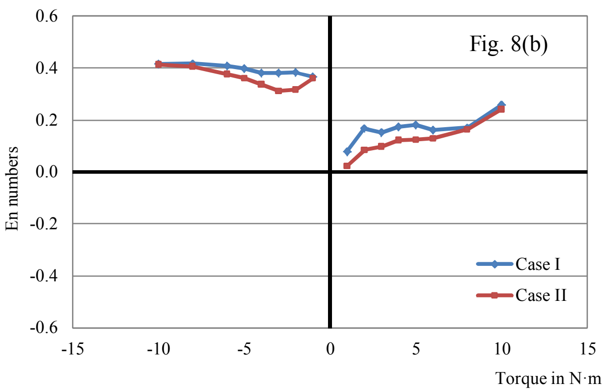
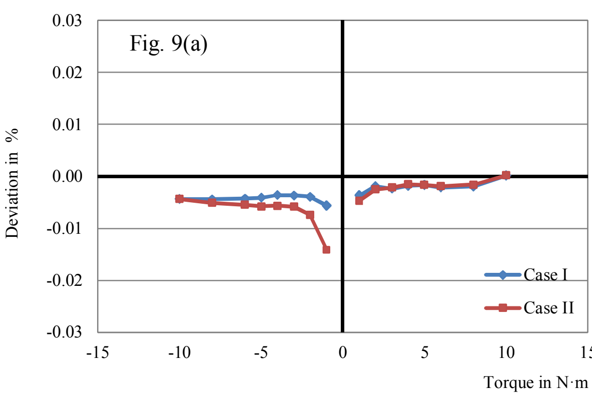


Fig. 8. Deviation value (a) and E_n ratio of comparison (b): when using weight balanced technique.

When using Δl which evaluated by using torque unbalanced technique, there were deviation between PTB and NIMT measurement within 0.0001% to -0.0142%. Slightly change from previous less than 0.006% corresponding to Δl values which are different from both techniques. And E_n ratio changed to be 0.25 to -0.09 as shown in Fig. 9. However comparison results were still satisfactory.



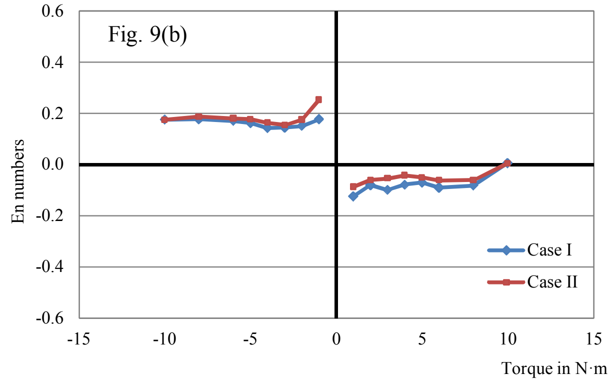


Fig. 9. Deviation value (a) and E_n ratio of comparison (b): when using torque unbalanced technique.

4. CONCLUSIONS

The length of thin sheet metal that used to be fulcrum and hung weight is mainly effect to position of the fulcrum.

Long thin sheet metal makes lever arm more swing. Lever arm will be less swing and easier handle when use short thin sheet metal. However, when using long thin sheet, position of fulcrum will be more stable than other. It is one of the most important parameter that contributing to measurement uncertainty. There is a few different value of Δl depending on evaluation method. A study would be continued in order to clarify and improve evaluation method. Finally the comparison results between PTB and NIMT in range of 1 N·m to 10 N·m were satisfactory even measurement results were taken from different Δl which evaluated from two methods, weight balanced technique and torque unbalanced technique.

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