The First 100-kN Force Interlaboratory Comparison in Thailand

Veera Tulasombut[1] Patjarapon Tiangtrong[2] Kittipong Chaemthet[3]
Department of Mechanical Metrology, National Institute of Metrology (Thailand),
Bangkok, 10400, Thailand
Tel: 0-23543700 ext.111 Fax: 0-23543693 E-mail: veera@nimt.or.th[1]

บทคัดย่อ

แรง เป็นหน่วยอนุพันธ์ที่ประกอบด้วยหน่วยพื้นฐานคือ มวลและค่าอัตราเร่งเนื่องจากแรงโน้มถ่วงของโลกตามสมการ F=mg ศาสตร์การวัดแรงได้นำมาประยุกต์ในหลายสาขา เช่น อุตสาหกรรมและการคมนาคม โดยเฉพาะการก่อสร้าง อีกทั้งมีบทบาทสำคัญในการรับรองความปลอดภัย การประหยัดต้นทุน และช่วยในการออกแบบที่เหมาะสม ในการรับประกันการวัดแรงอย่างถูกต้องนั้น เครื่องวัดแรงและอุปกรณ์ที่ใช้ในการนี้จะต้องได้รับการสอบเทียบจากห้องปฏิบัติการระดับอ้างอิง ห้องปฏิบัติการเหล่านี้มีเครื่องวัดแรงมาตรฐานระดับอ้างอิงซึ่งสามารถสอบกลับไปยังหน่วยพื้นฐานได้และใช้ถ่ายทอดค่าแรงไปยังเครื่องมือและอุปกรณ์วัดแรงที่ใช้ในภาคธุรกิจอุตสาหกรรมต่างๆ ในการตรวจสอบความสามารถในการวัดของห้องปฏิบัติการนั้น วิธีหนึ่งคือการเปรียบเทียบผลวัดระหว่างห้องปฏิบัติการ โดยการหมุนเวียนเครื่องมือวัดแรง (load cell) ตัวอย่างที่กำหนดให้ห้องปฏิบัติการที่เข้าร่วมวัด แล้วหาค่าเบี่ยงเบนจากห้องปฏิบัติการอ้างอิง บทความนี้รายงานผลของการเปรียบเทียบผลวัดแรงครั้งแรกอย่างเป็นทางการในประเทศไทยระหว่างห้องปฏิบัติการระดับอ้างอิง เครื่องมือที่ใช้หมุนเวียนเป็นโหลดเซลล์แรงอัดขนาด 100 กิโลนิวตันพร้อมอุปกรณ์เสริม ขั้นตอนการสอบเทียบอิงพื้นฐานจาก ISO 376:1999(E) โดยมีการปรับเปลี่ยนเล็กน้อยเพื่อความสะดวกของผู้เข้าร่วม ผลที่ได้ออกมาเป็นที่น่าพอใจเนื่องจากทุกห้องปฏิบัติการมีค่าเบี่ยงเบนจากห้องปฏิบัติการอ้างอิงอยู่ในเกณฑ์ที่ยอมรับได้

Abstract

Force is a derived unit consisting of mass and gravity as base units, according to the mathematical model F=mg. The science of force measurement is applied in various fields, such as industry and transport, especially the construction sector. It has a crucial part in assuring safety, cost-effectiveness, and sufficient design. In order to ensure optimal force measurement, the instruments used for this purpose must be calibrated by reference laboratories. Each of these laboratories possess reference standards which are used to transfer the force values to the force-measuring instruments. To inspect the measurement capability of a laboratory, one method is to conduct interlaboratory comparisons, circulating an artifact among participants for measurement, and then determining the deviation from the reference laboratory. This paper describes the results of the first official force interlaboratory comparison among Thailand's reference laboratories. The circulated artifact was a 100-kN compression load cell, together with its accessories. The procedure was based on ISO 376:1999(E) with minor adaptations to accommodate each participant. Final results were satisfactory, all within the acceptable deviation limit from the reference values.

Keywords: force, uncertainty, force-comparator, lever-type

1. Introduction

Until recently, there has never been an official interlaboratory comparison in the field of force metrology in Thailand. Therefore, the National Institute of Metrology (Thailand), or NIMT, proposed a force interlaboratory comparison among Thailand's main reference laboratories possessing the required measurement capability, with NIMT as the co-ordinating laboratory. The objective was to gather information regarding the force measurement capability of each participant, and to exchange technical knowledge and ideas to further the improvement of force metrology in Thailand.

2. Equipment

The artifact chosen for this intercomparison was a 100-kN compression load cell, together with its digital measuring unit and accessories. Three of the participants possess force-comparator type machines, which transfers force from a reference force transducer to the unit under calibration (UUC); in this case the artifact. One participant uses a 100-kN. lever-type deadweight force machine as a force generator.

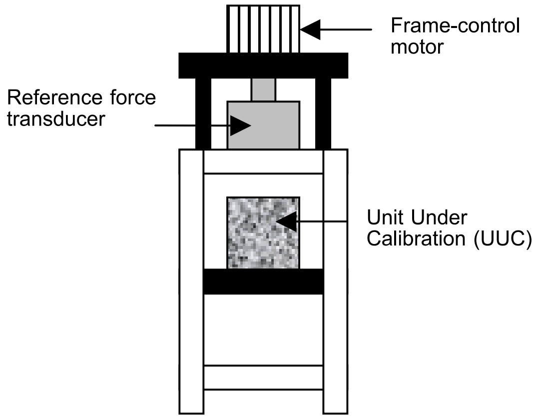

Fig. 1 Force-comparator type machine

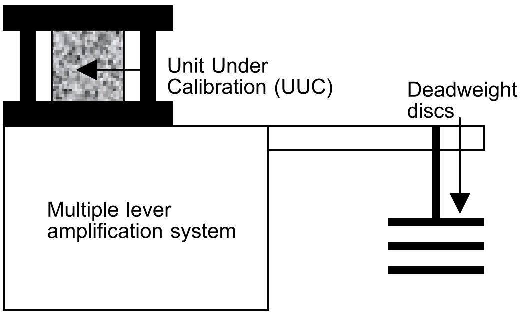

Fig. 2 Lever-type deadweight force machine

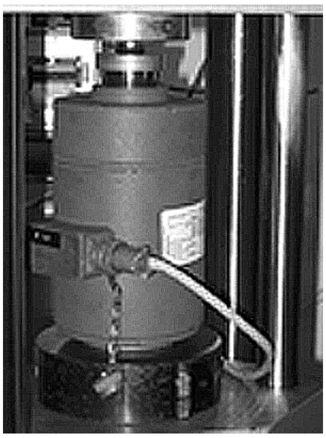

Fig. 3 The artifact load cell used in this intercomparison

3. Principle of intercomparison

The calibration procedure was based on ISO 376:1999(E). The artifact was measured at three rotation positions around the axis; 0^0, 120^0, and 240^0. Two increasing force cycles, ten steps each starting from 10% of the nominal force to 100%, were applied to the artifact at the initial position (0^0) to determine the repeatablility. Then it was rotated 120^0 and underwent the same force application as that of 0^0, with the addition of a decreasing force cycle at exactly the same force steps as the increase cycle. This is in order to determine the artifact's hysteresis. The artifact was rotated once more in the same direction 240^0 from the initial position, and the increase-decrease cycles were applied as at 120^0. The average values obtained from the first 0^0 cycle, the 120^0-increase cycle, and the 240^0-increase cycle are used to obtain the artifact's reproducibility.

Prior to each position, the artifact was pre-loaded three times with the maximum calibration force for a duration of 1 minute. The intervals between each time at zero load was 1 minute before applying the force again. After the third pre-load, 5 minutes were allowed for stabilization before starting measurements. At each force step, force was applied for 1 minute before reading the deflection from the artifact's digital indicator. Then force was increased or decreased to the next step, depending on the cycle.

Due to one participant's use of the lever-type deadweight force machine, the force steps used in this intercomparison had to correlate with the force generated by each deadweight disc and the local gravity.

The artifact circulation schedule started from NIMT as the pilot laboratory, then on to three other participants, with an allotted period of one week each. When the third participant completed their measurement, the artifact was delivered to NIMT for the final measurement.

4. Results of the comparison

Table 1 shows the average deflection of the artifact, taken from the first increase cycles of all three rotation positions. The values of NIMT are shown as the mean of the first and last measurements.

Table 1 Deflection of the artifact at each force loading

Force (kN)	NIMT (mV/V)	TISTR[1] (mV/V)	THAI[2] (mV/V)	RTAF[3] (mV/V)
10	0.2964	0.2966	0.2966	0.2963
20	0.5932	0.5931	0.5932	0.5933
30	0.8899	0.8898	0.8898	0.8899
40	1.1866	1.1864	1.1865	1.1864
50	1.4834	1.4832	1.4832	1.4827
60	1.7802	1.7800	1.7800	1.7800
70	2.0770	2.0768	2.0768	2.0765
80	2.3739	2.3737	2.3738	2.3739
90	2.6707	2.6707	2.6708	2.6706
100	2.9676	2.9681	2.9678	2.9675

[1] Thailand Institute of Scientific and Technological Research
[2] Thai Airways International Public Co.,Ltd.
[3] Royal Thai Air Force

Figure 4 shows the relative deviation from the average measured values of NIMT, in ppm. This is because NIMT was the reference laboratory for the intercomparison and the artifact was calibrated at NIMT before and after all participants. This does not mean that the NIMT measurements are the true values.

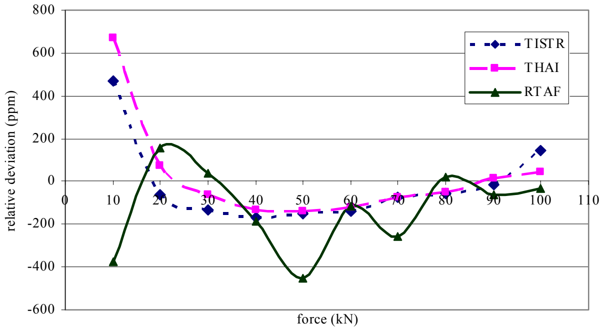

Fig. 4 The relative deviation from the pilot laboratory

The uncertainty at each force load was obtained from the following components

u_b : reproducibility uncertainty

$u_{b'}$: repeatability uncertainty

u_v : reversibility (hysteresis) uncertainty

u_r : indicator resolution uncertainty

u_s : reference standard uncertainty

With a coverage factor of 2, providing a confidence level of approximately 95%, the expanded uncertainty was determined from

$$U = 2\sqrt{(u_b)^2 + (u_{b'})^2 + (u_v)^2 + (u_r)^2 + (u_s)^2} \quad (1)$$

Table 2 shows the expanded uncertainty of the artifact at each force load, in %.

Table 2 Expanded uncertainty of the artifact at each force load

Force (kN)	NIMT (%)	TISTR (%)	THAI (%)	RTAF (%)
10	0.107	0.043	0.180	0.458
20	0.076	0.046	0.130	0.279
30	0.057	0.049	0.130	0.244
40	0.049	0.048	0.130	0.265
50	0.043	0.048	0.083	0.084
60	0.040	0.048	0.080	0.163
70	0.034	0.049	0.077	0.142
80	0.030	0.050	0.075	0.109
90	0.028	0.049	0.073	0.078
100	0.028	0.040	0.072	0.070

The assessment of the participant measurement capabilities were based on the E_n numbers of ISO/IEC Guide 43-1. The E_n numbers are calculated using a standard statistical technique for comparing values and are derived from the following expression

$$E_n = \frac{X_{ref} - X_{lab}}{\sqrt{(U_{lab})^2 + (U_{ref})^2}} \quad (2)$$

where X_{ref} : reference laboratory''s results

X_{lab} : participant's results

U_{lab} : participant's expanded uncertainty

U_{ref} : reference laboratory's expanded uncertainty

Table 3 The E_n numbers of participating laboratories

Force (kN)	TISTR	THAI	RTAF
10	-0.41	-0.04	0.08
20	0.07	-0.05	-0.05
30	0.17	0.04	-0.01
40	0.25	0.10	0.07
50	0.23	0.15	0.48
60	0.22	0.13	0.07
70	0.13	0.09	0.17
80	0.10	0.06	-0.02
90	0.03	-0.02	0.08
100	-0.29	-0.06	0.04

An E_n number between -1 and +1 indicates an acceptable degree of compatibility between the participant's result and that of the reference laboratory where the quoted uncertainties are taken into account. Figure 5 is a graph indicating the E_n ratio at each force loading of each participant compared with the reference laboratory (NIMT).

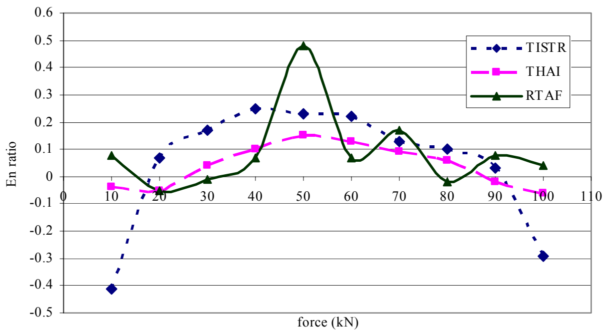

Fig. 5 The E_n ratio at each force loading

5. Benefits of correct force measurement

The forces acting within and between parts of a mechanism are fundamental to the safety, assembly and use of any piece of equipment. The measurement of those forces is vital to understanding and monitoring the activity which the machine is designed to undertake. Force measurement is needed in many industries, and not only for technical purposes but also for cost-effectiveness. To make reliable and accurate measurements of force, it is therefore necessary to use proper measurement techniques.

6. Conclusion

The E_n number determination indicated that all participants' results were within the acceptable deviation limit from the reference laboratory. This interlaboratory comparison in force proved satisfactory, and further details of possible improvement in measurement were discussed, such as vertical alignment of the artifact or calibration machine. Expectations are that this will serve as a precedent for future interlaboratory comparisons in the field of force metrology.

7. Acknowledgements

The authors gratefully acknowledge the Precision Measurement Equipment Laboratory, Royal Thai Air Force for providing the artifact used in this intercomparison. Also the valuable technical input from personnel of Thailand Institute of Scientific and Technological Research (TISTR) and the Reference Standards Laboratory, Thai Airways International Co., Ltd. is greatly appreciated.

References

[1] International Organization for Standardization "ISO 376 Metallic materials – Calibration of force-proving instruments used for the verification of uniaxial testing machines", 1999

[2] International Organization for Standardization "ISO/TAG4 Guide to the Expression of Uncertainty in Measurement", 1993

[3] International Organization for Standardization "ISO/IEC Guide 43-1 Proficiency Testing by Interlaboratory Comparisons Part 1: Development and Operation of Proficiency Testing Schemes", 1999

[4] The Institute of Measurement and Control "Guide to the Measurement of Force", 1998