A New Proficiency Testing (PT) Evaluation for Conformity Assessment of Roughness Measuring Instruments

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Abstract. Precise surface roughness measurement is crucial as it has a direct effect on surface quality. In this work, Proficiency Testing (PT), which is an important process for conformity assessment, was conducted based on a portable roughness tester as a standard measuring instrument. There were seven calibration laboratories from Thailand that participated in the PT with a technical protocol that was designed by NIMT. The roughness tester was provided by NIMT. Two roughness standards with different roughness values (Ra ≤1 and Ra >1) were prepared by each calibration laboratory. The PT measurands were common roughness parameters such as Ra and Rsm. As the roughness measuring instrument is based on LVDTs, we propose here a new proficiency testing evaluation which involves the calibration of the measuring instrument in the PT evaluation procedure. The PT results, according to ISO/IEC 17043, shows that six out of the seven participating laboratories indicated satisfactory performance ($|En| \leq 1$) where the measurement uncertainty was based on a 95% confidence level. The PT results and evaluation procedure for conformity assessment of the roughness measuring instrument are presented. Finally, measurement techniques to improve measurement quality are recommended.

1. Introduction

Surface finishing is an important process for manufacturing industries. Accurate surface roughness measurement is crucial as it has a direct impact on quality of machine parts. In Thailand, the National Institute of Metrology of Thailand (NIMT) provides traceability of reference roughness standards and roughness measuring instruments. NIMT is also a coordinator to organize proficiency testing (PT), which is an important process for conformity assessment [1]. Previously, PT of surface roughness measurement has been focusing on roughness specimen [2]. Roughness specimens are typically used as a reference standard for calibrating a portable roughness measuring instrument (roughness tester). A roughness tester is widely used in manufacturing industries due to its advantages such as compactness and lightness. However, uncertainty of roughness tester calibration is not only arises from reference roughness standards. There are other sources of uncertainties such as environmental errors, human errors, setting of measuring condition such as cut-off wavelength, evaluation length [3-4]. Therefore, PT on roughness tester calibration is also important. In this work, we organized a PT based on a portable roughness tester. PT evaluation for conformity assessment of the roughness tester including method, results, analysis and discussion will be presented. A new evaluation method that utilizes a linearity of a stylus probe of the roughness tester in the calibration process will be discussed in detail.

2. Methodology

Surface laboratory of NIMT organized the PT using roughness tester (Surtronic S128 by Taylor Hobson) as an artifact. There were seven laboratories participated in the program. All participants required to prepare at least two high accuracy roughness standards with nominal value of Ra ≤1 and Ra >1. Traceability evidence of roughness standards i.e. calibration certificates must be provided. Cutoff wavelength and bandwidth setting were recommended to follow ISO4288:1996 using Gaussian filter. Participants were advised to measure roughness parameters according to laboratory procedures, which should include Ra and Rsm values. Noted that all participants were informed not to use "calibration" function to calibrate the roughness tester.

3. Results

PT results from NIMT and all participants are shown in Table 1. Participants laboratories are named by code A-G. Reference values shown in the table are roughness standard values used in the PT by each laboratories, which obtained from the certificates. Measurement uncertainties, shown in blacked after the results, are based on 95% level of confidence (k=2).

	Ra		Rsm	
Code	**Reference value**	**Measured value**	**Reference value**	**Measured value**
NIMT-1	0.834(0.04) 3.125(0.05)	0.771(0.142) 3.281(0.478)	80(0.58) 100(0.58)	89.640(2.674) 108.200(3.135)
A	0.398 (0.04) 2.892(0.04)	0.390(0.083) 3.010(0.174)	15(0.58) 94(0.58)	16.000(2.044) 101.000(12.140)
B	0.41(0.06) 2.911(0.08)	0.388(0.058) 2.980(0.198)	15(0.58) 94(0.58)	16.204(1.038) 102(6.554)
C	2.991(0.037) 0.476(0.037)	2.933(0.103) 0.483(0.092)	N/A N/A	N/A N/A
D	2.942(0.02) 0.459(0.03)	2.250(0.430) 0.470(0.420)	100(0.58) 56.5(8.79)	109.000(0.990) 35.000(14.000)
E	0.403(0.01) 3.163(0.04)	0.350(0.080) 3.270(0.185)	N/A N/A	N/A N/A
F	0.399(0.01) 2.967(0.04)	0.376(0.083) 3.014(0.534)	N/A N/A	N/A N/A
G	5.99(0.142) 0.83(0.023)	6.070(0.154) 0.806(0.154)	N/A N/A	N/A N/A
NIMT-2	0.0834(0.04) 3.125(0.05)	0.753(0.143) 3.279(0.533)	80(0.58) 100(0.58)	89.040(2.762) 106.760(3.279)

Table 1: Summary of laboratory measurement results in μm.

4. Analysis and Discussion

Conventional statistical evaluation methods such as z-scores and En ratio rely on a reference laboratory's value to evaluate participating laboratories. However, in this PT, participants prepared their own roughness standards. It is, therefore, impractical to evaluate participating laboratories performance based on a direct comparison with NIMT as a reference laboratory result.

In this PT program, a roughness value for each roughness standard was obtained from its calibration certificate and used as a reference value. As the portable roughness tester is based on LVDTs, calibration factor (or correction factor) was calculated to correct the measured results. The calibration factor (Cf) is determined as,

$$C_f = \frac{v_{ref}}{v_{mea}} \quad \text{Eq.1}$$

where v_{ref} is the reference value obtained from calibration certificate and v_{mea} is the value measured using roughness tester. By plotting v_{ref} against v_{mea}, a correction factor was obtained from a slope of the curve. Assuming a linear relationship between *υ*mea and *υ*mea at all ranges, a correction factor based on Rsm and Ra for each laboratory was calculated based on linear regression using least square method, as shown in table 2. Note that the correction factor of NIMT and participant lab codes A,B and E-G are lower than 1, while the correction factor of lab C and D are higher than 1. This indicates opposite correcting direction of the measured values. In other words, the corrected value, or the measured value multiplied by it's correction value, of lab A-B and E-G will increases while lab C and D will decreases compared on measured value.

An inaccurate correction factor could result from human error of an operator or the quality of the reference standard. Cut-off wavelength setting, sampling length setting and improper alignment could also lead to error in the correction factor. These things were found to be at least partly responsible for the differences in the correction factors obtained from labs C and D compared to the other labs. To improve measurement quality, the cutoff wavelength and bandwidth setting must follow the standard described in ISO4288:1996.

Code	Correction factor	
	Rsm	Ra
NIMT-1	0.9113	0.9592
A	0.9309	0.9618
B	0.9182	0.9782
C	N/A	1.0189
D	0.9761	1.2937
E	N/A	0.9694
F	N/A	0.9856
G	N/A	0.9876
NIMT-2	0.9210	0.9607

Table 2. Summary of correction factor of Rsm and Ra.

The performance of the participants was evaluated based on normalized error (En), according to [1],

$E_n = \frac{v_{result} - v_{ref}}{\sqrt{U_{lab}^2 + U_{ref}^2}}$,where v_{result} is the corrected measurement result ($v_{result} = v_{mea} \times C_f$) , U_{lab} is the participant's expanded uncertainty at a 95% level of confidence and U_{ref} is the expanded uncertainty from a calibration certificate at a 95% level of confidence. According to ISO/IEC 17043[1], $|En| \leq 1$ indicates "satisfactory" degree of compatibility between the participant's result and the reference value, and is considered to be internationally acceptable. |En| outside this range indicates "unsatisfactory" performance which requires immediate investigation and corrective action. Figure 1 shows a Summary of corrected value of Ra and Rsm from all participants. As shown in Fig.1, |En| value shows generally good agreement between participants and the reference value. For labs A-C and E-G, the En values of Ra and Rsm are ≤ 1. Only two |En| values of Ra and Rsm were greater than 1, these were both from lab D.

In this PT, "unsatisfactory" |En| values could arise from various factors such as (i) inaccurate correction factor as described above (ii) misalignment of the stylus probe to the roughness standard

(iii) any other errors not included in the calculation of uncertainty. It was noted that most of the participating labs reported lower uncertainty than NIMT. This indicated that some sources of uncertainty were neglected. Therefore, further training of uncertainty calculation is recommended.

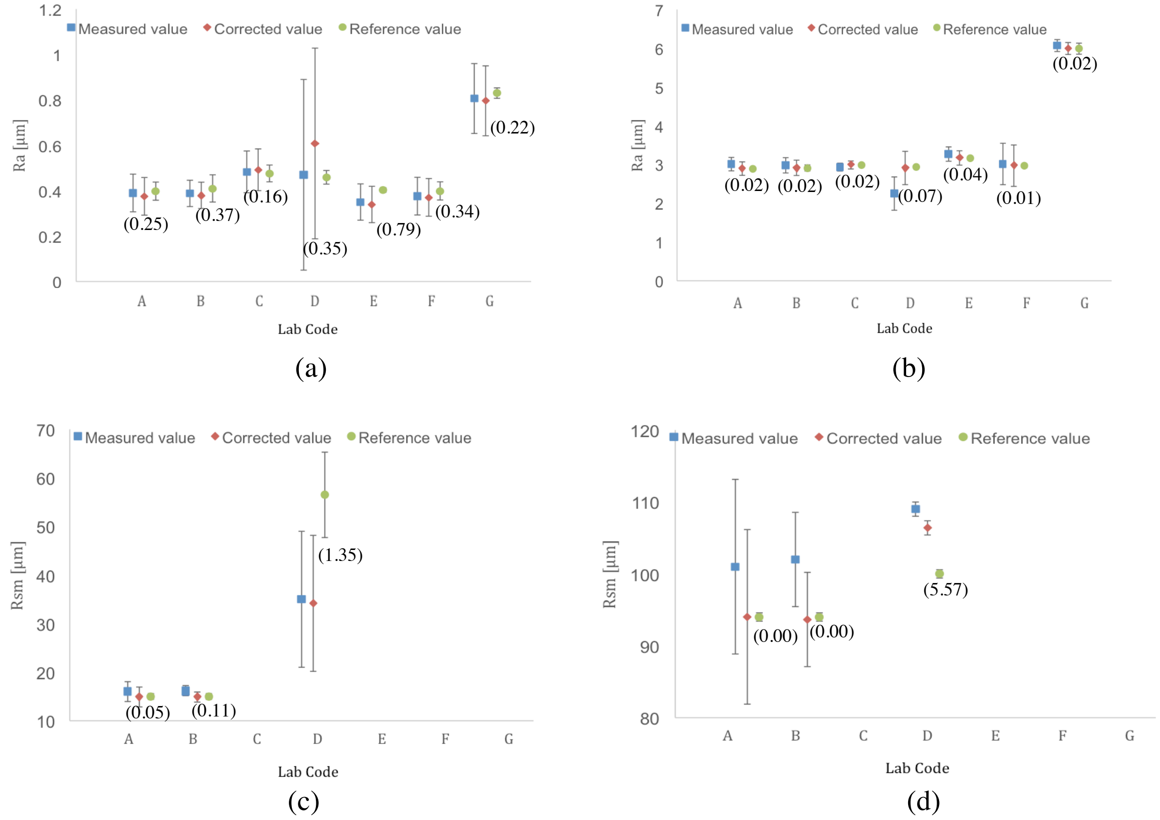

Figure 1. Summary of corrected value of Ra and Rsm from all participants (red circles) along with reference value (blue squares) using roughness specimens with Ra ≤1 (a-c) and Ra >1 (d-f). Error bars shown in the graph are expanded uncertainty at a 95% level of confidence (coverage factor K = 2). |En| value is shown in brackets below the measured value at each measurement.

5. Conclusion

A PT for conformity assessment of a roughness tester was conducted by NIMT. The PT was performed based on a new evaluation method that involves a correction factor for the roughness tester. The evaluation method proposed here could also be applied to other PTs based on LVDTs. The PT result of the roughness tester shows six out of seven participating calibration laboratories having satisfactory performance.

References

[1] International Organization for Standardization- Conformity assessment-General requirements for proficiency testing (ISO/IEC17043:2010(E))

[2] ARIF, S. M., CHUADHAR, K., & Singhal, R. P. (2008). Proficiency testing for surface roughness standard and groove depth standard. MAPAN-Journal of Metrology Society of India, 23(1), 11-20.

[3] Haitjema, H. (1998). Uncertainty analysis of roughness standard calibration using stylus instruments. Precision Engineering, 22(2), 110-119

[4] Stępień, K. (2015). Testing the accuracy of surface roughness measurements carried out with a portable profilometer. In Key Engineering Materials (Vol. 637, pp. 69-73). Trans Tech Publications.