First International Intercomparison of Computed Tomography Systems for Dimensional Metrology

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Abstract

This paper presents the preliminary results of the *"CT Audit"* project, which is the first international intercomparison of X-ray Computed Tomography (CT) systems for dimensional metrology. The intercomparison was organized and coordinated by the University of Padova, Italy, and involved institutions and companies in Europe, America and Asia. The interlaboratory comparison was based on the circulation of four calibrated items that were sent to each Participant together with detailed measurement procedures. The circulation involved 16 CT systems in total and was run from March 2010 to February 2011.

1 Introduction

Nowadays, X-ray Computed Tomography (CT) is increasingly used for dimensional metrology because of many advantages with respect to traditional coordinate measurement systems, as for example the possibility of non-destructive inspection of internal geometrical features and high density points acquisition. However, CT metrology lacks in traceability, due to additional error sources e.g. X-ray source, detector and interaction with material [1].

Intercomparisons are fundamental in metrology to establish the effectiveness and comparability of measurement methods, and to validate uncertainty claims [2]. For this reason, the University of Padova organized the first international intercomparison of CT systems for dimensional metrology. The research project *"CT Audit"* involved institutions and companies in Europe, America and Asia, including national metrology institutes, CT systems manufacturers, research institutes, and industrial users. Further details are given in the project's website www.gest.unipd.it/ct-audit.

2 *CT Audit* items and circulation

Each participant received the four calibrated items that are schematically shown in Fig. 1. The four items were protected in thin plastic sealed boxes, for several reasons: reducing the risk of damages, limiting contamination, and avoiding measurements with other sensors.

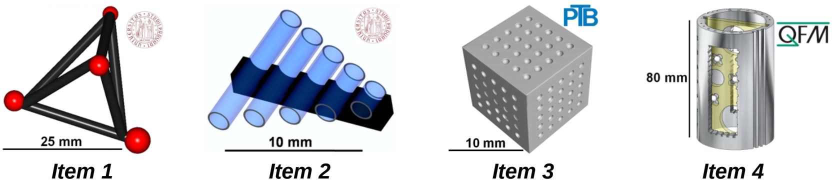

Fig. 1: Schematic representation of the four calibrated items used within the *CT Audit* intercomparison

The four objects are briefly described in the following.

Item 1, called "CT Tetrahedron", consists of four calibrated ruby spheres on a carbon fiber frame. It was developed by University of Padova, Italy.

Item 2, called "Pan Flute Gauge", is composed of five calibrated glass tubes of different lengths. It was developed by University of Padova, Italy.

Item 3, called "PTB Calotte Cube", consists of 75 spherical calottes on three sides of a titanium hollow cube. This item was developed by Physikalisch-Technische Bundesanstalt, Germany.

Item 4, called "QFM Cylinder", is made of a titanium cylinder and a ball plate with five sapphire balls. This item was developed by QFM − University Erlangen-Nuremberg, Germany.

Dimensional stability of the four items was verified with tactile CMM calibrations at the beginning and at the end of circulation. Items 1 and 2 were also checked with additional intermediate calibration during the circulation and revealed good dimensional stability, with deviations within calibration uncertainties.

Each participant was asked to provide measurement results according to well detailed measurement procedures given by the project coordinator. Furthermore, participants were requested to state expanded measurement uncertainties and uncertainty evaluation methods.

3 Preliminary results

Measurement results have been collected and analysed for the first eight participants, without reference to the chronological measuring order. Figure 2 shows the comparison of the results of distances measurements between spheres centres on item 1. As clearly visible, most of the participants performed such measurement task with deviations within 10 µm. However, the validity of uncertainty statements even for this simple measurement task is limited. In general, uncertainty evaluation is very problematic for CT systems users, since no international standard or guideline exists in this field.

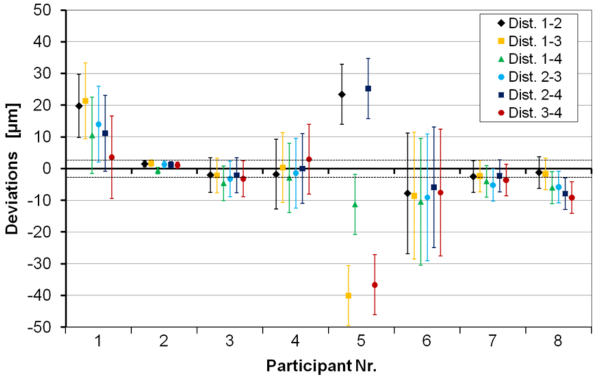

Fig. 2: Comparison of results from eight participants, with respect to measurement of spheres distances of Item 1. Error bars represent expanded uncertainties declared by participants. Dotted lines represent uncertainty of reference values.

Figure 3 shows, as an example, the results obtained from one of the participants in the measurement of spheres' diameter and form error (range of radial deviations between the points extracted from the measured sphere and the associated ideal sphere from Gaussian fitting). In general, for all participants, form error measurements are more problematic than measurements of dimensions.

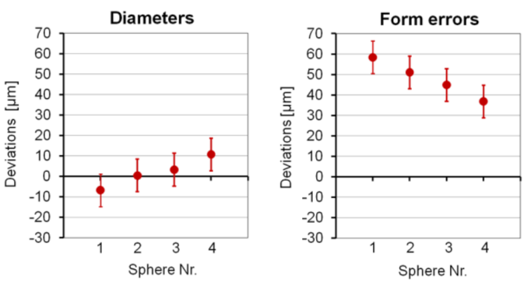

Fig. 3: Examples of results of diameters (left) and form errors (right) measurements on the four spheres of item 1, obtained from one of the participants.

Finally, Figure 4 illustrates the results obtained from one of the participants in the measurement of outer and inner diameters and lengths of the tubes of item 2. Deviations of outer and inner diameters are of opposite sign. This is a common trend for all participants and is a typical effect of threshold errors in CT measurements.

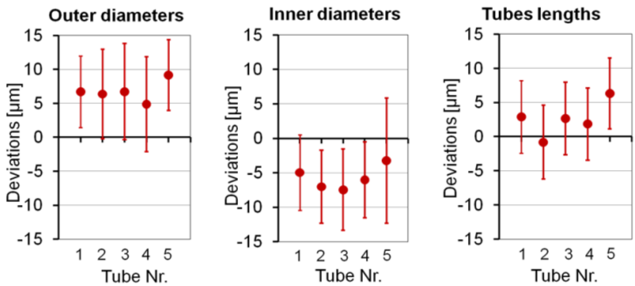

Fig. 4: Examples of results of outer diameters (left), inner diameter (centre) and lengths (right) measurements on the five tubes of item 2, obtained from one of the participants.

4 Conclusions and further developments

CT Audit, the first international comparison of CT dimensional measuring systems, has been running from March 2010 to February 2011. 16 CT systems were involved, from research centres, CT systems manufacturers and users, in Europe, America and Asia. Some preliminary results of the comparison were presented in this paper, with focus on specific measurement problems for CT systems.

Publication of the complete results report is expected for mid 2011. The main expected results are: (i) evaluation and comparison of Participants' measurements and uncertainty evaluation methods, (ii) identification of specific causes of typical measurement errors, and (iii) establishment of an international network of laboratories using CT dimensional measuring systems.

References:

[1] Kruth J.P., Bartscher M., Carmignato S., Schmitt R., De Chiffre L., Weckenmann A., (2011). Computed Tomography for Dimensional Metrology. Keynote paper. CIRP Annals, vol. 61/2 (in press).

[2] Carmignato S., Voltan A., Savio E., (2009). Metrological performance of optical coordinate measuring machines under industrial conditions. CIRP Annals, vol. 59/1, 497-500.