Key ideas on computed tomography measurement corrections applied to a conventional CT machine

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Abstract

This paper focuses on some of the issues that should be taken into account to use a conventional (i.e. non metrological) micro CT machine in dimensional metrology applications, paying special attention to two of the most important factors affecting measurement accuracy: threshold determination and scale factor. The paper presents a detailed explanation of the correction methods applied at University of Zaragoza for the measurement of two calibrated items used in the first international comparison of CT systems (CT Audit). Finally, the results of the measurements and the main conclusions of the work are shown.

1 Introduction

Nowadays commercial metrological CT machines are available and they boast the measuring capabilities and advantages of this technique. Unfortunately, due to the economic cost of new metrological CT machines, this technology is not always easily accessible. Therefore, some laboratories, research centres and universities are utilizing non-measuring oriented micro CT machines for different metrological applications. There are several factors which influence the loss of accuracy in CT machines [1,2]. Two of the most important are the threshold determination and the scale factor. Unfortunately it is still difficult to determinate the specific contribution of each of them to the total measurement error. This paper describes the correction methods applied at University of Zaragoza (UNIZAR) using a non-measuring oriented CT machine for the measurement of two of the calibrated items of the CT Audit intercomparison leaded by the University of Padova [3-5].

2 Materials and Methods

The first item is called "CT tetrahedron" and consists of four ruby spheres of different diameters, made of Synthetic ruby monocrystal and supported by a carbon fibre frame. The four spheres centres are ideally positioned on the vertexes of a tetrahedron with nominal side length of 25 mm. The frame is made with carbon fibre bars with 2 mm in diameter (Figure 1). The second item is called "Pan Flute Gauge" and consists of five glass tubes supported by a carbon fibre frame. The five tubes made of Borosilicate glass have same nominal diameters (inner diameter: 1.5 mm; outer diameter: 1.9 mm), but different lengths ranging from 2.5 to 12.5 mm (Figure 1). Both items were developed and calibrated at University of Padova. They were measured by a non-measuring oriented micro CT machine: UNIZAR CT machine, with an X-ray source power from 50 to 80 kV and maximum resolution of 8 µm.

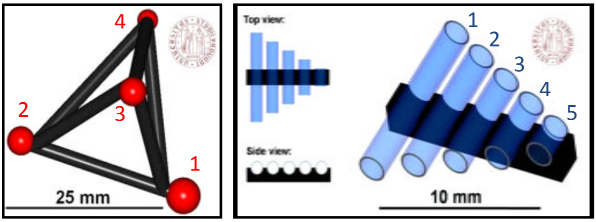

Figure 1: Item 1, CT tetrahedron, (left) and item 2, Pan Flute Gauge, (right) [5].

The correction methods developed by UNIZAR are applied for the independent correction of the threshold and the scale factor. For that, it is necessary to have reference measurements of a calibrated work-piece. The correction strategy used is geometry-dependant, so that, a classification of two types of work-pieces was made: type 1, where at least one of its dimensions remains stable despite the change in threshold (e.g. distance between the centres of two spheres), as item 1. Type 2: work-pieces with geometry similar to a tube, where a ratio between the outer and inner diameter can be established to perform the correction, as item 2.

The correction strategy for parts classified as type 1 was the following:

1. Determine the correction factor (Eq. 1) taking as a reference a dimension that is not affected by the threshold.

$$\text{Correction ratio}_{\text{Reference}} = \frac{\text{Length}_{\text{Reference}}}{\text{Length}_{\text{CT}}} \quad (1)$$

2. Adjust the threshold in order to get a correct measurement for the sphere diameter considering the following ratio (Eq. 2)

$$\text{Correction ratio}_{sphere} = \frac{\text{Sphere}_{Reference}}{\text{Sphere}_{CT}} \quad (2)$$

3. Apply the scale factor ratio to the CT measurements (Eq. 3).

$$\text{Measurement Corrected} = (\text{Correction ratio})(\text{Measurement CT}) \quad (3)$$

On the other hand, the steps taken for the correction process of item 2 were the following:

1. Determine the ratio between Inner Diameter (ID) and Outer Diameter (OD) of the reference measurement (Eq. 4). This ratio is used assuming that it does not depend on the scale factor.

$$\text{Ratio} = \frac{\text{Outer Diameter}}{\text{Inner Diameter}} \quad (4)$$

2. Calculate the same ratio for the CT measurements and adjust the threshold in order to get the same value as calculated in step 1.
3.
4. Once obtained the ratio in step 2, calculate the correction factor using equation 1

5. Apply the correction factor, calculated for the inner and outer diameter ratio, to the rest of the CT measurements (i.e. lengths) and obtain the corrected measurement.

3 Results

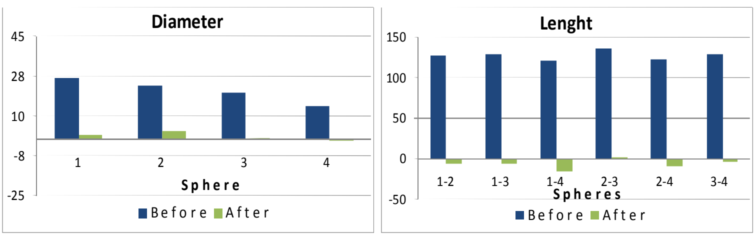

Figure 2: Diameter (left) and length (right) deviations (in µm) from reference values for item 1.

In Figure 2, the deviations between the measurements taken by the UNIZAR CT machine and the reference for item 1 before and after correction are shown. The absolute maximum deviation in diameter before correction is around 26.9 µm and the absolute average deviation is 21.2 µm, while the absolute maximum deviation after correction decreases to 3.5 µm and the absolute average error decreases to 1.5 µm. Regarding length, the absolute maximum deviation in distance between spheres decreases from 135.8 µm to 15.0 µm.

In Figure 3, deviations between the measurements taken by the UNIZAR CT machine and the reference for item 2 before and after correction are shown. The absolute average deviation of the inner diameter decreased from 4.2 µm to 2.2 µm. For the outer diameter the absolute average deviation decreased from 34.5 to 2.4 µm. Finally the absolute average deviation in the length decreased from 50.2 to 2.3 µm. In the case of the measurement of the length, the reference value was not known prior to testing.

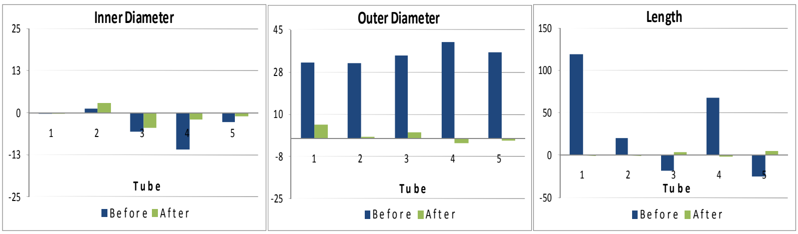

Figure 3: Inner diameter (left), outer diameter (centre) and length (right) deviations (in µm) from reference value for item 2.

4 Conclusions

The results obtained after correction shows a sensitive reduction of the measurement deviations. In the CT Audit inter-comparison the UNIZAR CT results after correction had the most significant reduction in the measurement deviations. These results might open the field to use conventional CT machines for measuring activities, even more taking into account that, the measuring time, highly dependant on the operator expertise to adjust the scanning parameters, may be considered similar for both sorts of CT machines.

References

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