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Verification of a CT scanner using a miniature step gauge

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Abstract

The work deals with performance verification of a CT scanner using a 42mm miniature replica step gauge developed for optical scanner verification. Errors quantification and optimization of CT system set-up in terms of resolution and measurement accuracy are fundamental for use of CT scanning in dimensional metrology. Influence of workpiece orientation, magnification, source-object-detector distances and surface extraction method on metrological performances of a CT scanner was evaluated. Results show that the position of the workpiece in the CT cabinet is fundamental to get reliable measurements, while the highest magnification (best resolution) does not assure the best accuracy.

1 Introduction

A 42mm-long replica step gauge, developed for optical scanner verification [1, 2] was used to evaluate accuracy of an industrial CT scanner. Novo Nordisk A/S, leading company in development of products for diabetes care, uses CT scanning for defects analysis and dimensional quality control in their product development. Attention was paid on documenting influence of selected factors affecting accuracy of CT measurements, particularly those that can be set by the operator. The step gauge was chosen because it has similar dimensions and material of parts commonly scanned. In particular, accuracy of measurements obtained from positioning the step gauge in a vertical position was investigated.

2 Experimental investigations

The influence factors considered were: workpiece orientation, magnification, source-object-detector distances and the threshold method used for surface extraction. A Nanotom® CT scanner from GE Phoenix-xray was used for the present investigation. Experimental tests were performed orienting the workpiece in two directions, vertical and at 45°, as shown in Figure 1. Metrological performance of the CT scanner was evaluated by computing the error of indication for size measurement, *E*, as suggested in the VDI/VDE 2617-6.2 guidelines. Four incremental distances on the step gauge grooves were measured unidirectionally. The overall *E* was computed as the maximum absolute value of the four obtained distances for each setup. Reference measurements were taken using a tactile coordinate measuring machine [1, 2].

a) b)

Figure 1: Orientation of the step gauge in the scanner cabinet: a) vertical position; b) inclined 45° with respect to the rotation axis.

2.1 Tests with step gauge positioned vertically

Having the step gauge mounted vertically, three setups were considered: two with the same magnification, corresponding to a voxel size (VS) = 20µm and the third setup with larger magnification, corresponding to a VS = 30µm. In the two cases with the same magnification, different distances between the x-ray source and the detector were chosen (SDD parameter, see Table 1). In the first case the detector was closer to the x-ray source. The other parameter considered was the threshold technique applied to extract the surface (global and local thresholding method).

Errors of indication for size measurement, *E*, obtained in the different setups are reported in Figure 2. Results show that the higher magnification does not assure the best accuracy. This is due to two effects. In the first instance, noise at the step gauge borders is present because of interaction between the x-ray cone beam source and straight surfaces perpendicular to the rotation axis. The effect is more severe when the incidence angle is bigger (i.e. workpiece and x-ray source are closer), even if the same magnification (voxel size) is chosen. Another effect is introduced, due to blurring. As the workpiece is moved closer to the x-ray source, getting higher magnification, more blurred images will be obtained because of the finite dimension of the x-ray spot size. Both effects were also pointed out in [2]. Concerning surface extraction, results obtained with local thresholding are generally more accurate than with global thresholding. Only in Setup 1, *E* values obtained with global threshold were sometimes better. This could be due to amplification of local noise that takes place with local thresholding, as it can be seen on the CT scans for Setup 1.

Table 1: Parameters setup used in the experiments

Parameter	Setup 1	Setup 2	Setup 3
Magnification	2.5x (SDD=275mm)	2.5x (SDD=500mm)	1.667x (SDD=500mm)
Voxel Size	20μm	20μm	30μm

2.2 Tests with step gauge positioned at 45°

Further tests were accomplished by positioning the step gauge tilted 45° with respect to the rotation axis of the scanner. A comparison to results obtained with the step gauge positioned vertically for the first two setups (same magnification) was made. All results (see Figure 2) show that by positioning the step gauge at 45° it is possible considerably to improve values of *E* by more than 50% with respect to the vertical position, because of a significant reduction of border noise on the flat surfaces of the steps.

3 Conclusions

Optimization of positioning of a workpiece in the CT scanner cabinet is important to enhance accuracy of CT measurements. Influences of the workpiece orientation, system magnification, source-object-detector distances and surface extraction method on an industrial CT scanner performance were evaluated using a replica step gauge, already used for optical scanner verification. Results show that the position of the workpiece in the measuring volume is fundamental to obtain reliable measurements. Important improvements of accuracy are obtained by positioning the workpiece not vertically but inclining it by 45° with respect to the rotation axis.

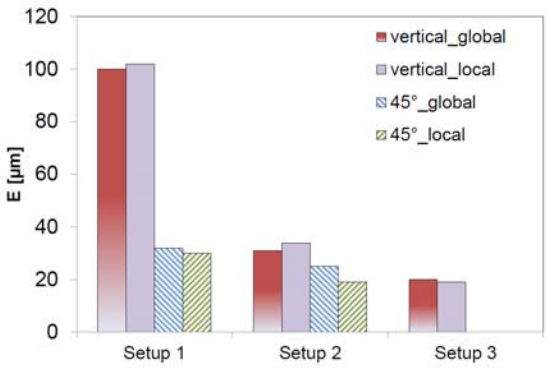

Figure 2: Errors of indication for size measurements with step gauge positioned vertically (Setup 1, Setup 2, Setup 3) and with step gauge positioned at 45° (Setup 1, Setup 2). Global and local thresholding methods were used for surface extraction.

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