Traceability investigation in Computed Tomography using reference objects

Alexandra Kraemer¹, Alessandro Stolfi², Timm Schneider¹, Leonardo De Chiffre², Gisela Lanza¹

¹wbk Institute of Production Science, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany, e-mail: alexandra.kraemer@kit.edu, gisela.lanza@kit.edu

²Department of Mechanical Engineering, Technical University of Denmark (DTU), Produktionstorvet Building 425, Kgs. Lyngby, Denmark, email: alesto@mek.dtu.dk, ldch@mek.dtu.dk

Abstract

This paper concerns an investigation of the accuracy of Computed Tomography (CT) measurements using three different workpieces: a multi-material step gauge manufactured at DTU and industry-inspired mono-material workpieces manufactured by wbk. Several dimensional and geometrical measurands, including a multi-material length were considered. The objects were calibrated using three CMMs and inspected using two CTs having different metrological performance. Quantification of the measurement uncertainty for CT measurements was also achieved using two different approaches. Metrological compatibility between CTs and between CTs and CMMs was quantified using the $E_a$ value concept.

Keywords: Computed Tomography, Metrology; Measurement Uncertainty;

1 Introduction

Small components are increasingly used in innovative industrial products. Such parts are extremely complex and demand complex strategy measurements and multiple setups. Computed Tomography (CT) provides a new tool for coping with the complexity, establishing a holistic dimensional metrology on a workpiece [1-2]. The use of X-rays as sensor allows penetrating a large variety of materials and enabling the complete surface measurement of small and internal features which would be inaccessible using other measuring instruments. Just scanning a workpiece once, high information density can be obtained, making savings on the amount of measurements required as well as increasing the reliability of measurements. CT removes the physical interaction with the parts, cancelling the workpiece deformations and the costs associated with design and manufacturing of dedicated fixturing systems. These are significant advantages over the traditional coordinate measuring machines (CMMs). On the other hand, the use of CT for dimensional measurements does not provide the same level of traceability as is the case with a CMM. This study reports performance of two CTs in measurement of different workpieces with difference measurands and materials. Special attention was paid to quantifying measurement uncertainty and the metrological compatibility between CTs and CMMs.

2 Workpiece

The first test reference object is a multi-material assembly comprising a cylindrical step gauge made out of aluminium and a tube made of glass and two fastening caps [3]. The cylindrical step gauge is a 56 mm long item with 6 grooves at 3.50 mm steps, produced by milling from a 14 mm diameter extruded rod. The assembly includes both mono-material measurands such as uni-directional and bidirectional lengths on the gauge and multi-material measurands, defined as the distances between the top of teeth of the gauge and the tube. The second object, named ED housing [4], took inspiration from the housing of electronic devices, while exhibiting multiple features for length measurement as well as diameter measurements of eight bores with diameters ranging from 2 mm to 5 mm. This reference object was manufactured in aluminium alloy as well as PEEK. The third reference object is a stepped cap which incorporates multiple inner and outer diameters [4]. The outer geometry consists of five coaxial cylindrical surfaces of different sizes. This reference object was manufactured in aluminium alloy as well as PEEK.
3 Measurements

CMM Measurements were performed using Zeiss OMC 850, Zeiss O-Inspect 322 and Werth Video Check HA 400 in temperature controlled laboratories both at wbk and DTU. In addition, two sets of CT measurements were performed: One was conducted on a Nikon XT H 225 CT available at DTU, the other one on a Zeiss Metrotom 800 available at wbk. The objects were mounted in a low absorption fixture from polystyrol. Scan parameters for the scans of the ED housing object are displayed in table 1. The evaluation of the scans were performed using a standardized procedure in VGStudio Max. For segmentation, a local thresholding method was used. The measurement uncertainty for CT measurements was estimated using two different approaches. In addition, the metrological compatibility between CTs and between CTs and CMMs was quantified using the $E_\theta$ value concept.

<table>
<thead>
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<th>Parameter</th>
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<tr>
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<td>Current</td>
<td>µA</td>
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<tr>
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<tr>
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<td>Prefilter Copper</td>
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Table 1: Scan parameters for measurement of PEEK stepped cap (CT at wbk).

References