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Cantatore, Angela; Angel, Jais Andreas Breusch; De Chiffre, Leonardo

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Material investigation for manufacturing of reference step gauges for CT scanning verification

A. Cantatore, J. Angel, L. De Chiffre
Department of Mechanical Engineering, Technical University of Denmark, Building 425, Produktionstorvet, DK-2800 Kgs. Lyngby, Denmark

acan@mek.dtu.dk

Abstract

This work deals with the study of stability and material investigation for manufacturing of step gauges for CT scanning verification. Four replica step gauges were fabricated using a bisacryl material for dental applications and the stability over five months was monitored using a tactile CMM. The material was unstable, probably due to a modification of the chemical composition which lowered the hardness. New step gauges were manufactured through milling. Polyetheretherketone (PEEK) and Polyp-phenylenesulphide (PPS with 40% glass) fulfil the requirements regarding hardness and mechanical properties and two series of five step gauges (one series for each material) were manufactured by milling. Results show a significant improvement in terms of form stability and surface geometry quality of the new step gauges with respect to the replica step gauges in Luxabite, as reported below.

1 Introduction

A 42mm-long replica step gauge (2 mm reference step length and 4 mm pitch), originally intended for optical scanner verification, was moulded in February 2009 using a bisacryl material for dental applications (Luxabite). Good stability of the step gauge was assessed over a period of 6 months, by computing incremental step lengths with both uni-directional and bi-directional strategies using a tactile coordinate measuring machine (CMM) [1]. The item was used for performance verification of a CT scanner with good results in terms of error characterization and system optimization [2]. In order to better characterize material stability, a wider sample was chosen and new four replicas were moulded in October 2010. The stability was investigated over five months (from March 2011 to August 2011). The results show average deviations ranging from 3 µm to 9 µm for uni-directional distances and deviations ranging from 12 to 27 µm for bi-directional ones, with expanded uncertainty (confidence level = 95%) higher than 30 µm for same measurands. These high values point out problems associated with measurement repeatability and form errors, due to the presence of holes in correspondence to the CMM probing points (average peak to valley height = 17 µm and average maximum width = 345 µm, measured with an Infinite Focus microscope by Alicona). The conclusions are that the material is not stable enough to be employed for reference items, as the manufacturing and replication did not allow to reach sufficient surface cooperativeness. This discrepancy with previous results can be due to the fact that in one year the chemical composition of the material was changed.

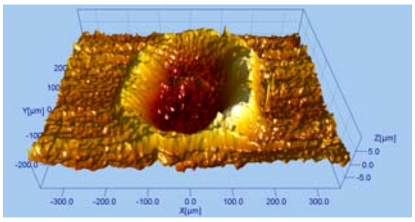

Figure 1: Examples of holes present on the measurement surfaces of Luxabite step gauges, measured with an Infinite Focus microscope

2 Material investigation for manufacturing of reference step gauges

Starting from these results, an investigation on proper materials for manufacturing of reference step gauge for CT scanning applications was carried out. Focus was kept on plastic materials, since they are commonly used in industrial CT scanning. Two materials were selected: Polyetheretherketone (PEEK) and Polyp-phenylenesulphide (PPS with 40% glass). These polymers fulfil requirements in terms of hardness, mechanical properties, surface cooperativeness and stability. Two series of five step gauges (one series for each material) were manufactured by milling. This process improved significantly the surface quality with respect to replica step gauges in Luxabite, with form errors of the order of 5 µm for the PEEK step gauges and of 3 µm for the PPS with 40% glass step gauges. The material hardness results also improved. It was measured using a Vickers hardness test, taking average and standard deviation of five repeated measurements. (Figure 3). An increase of around 50% with PEEK and PPS with 40% glass with respect to Luxabite is detected.

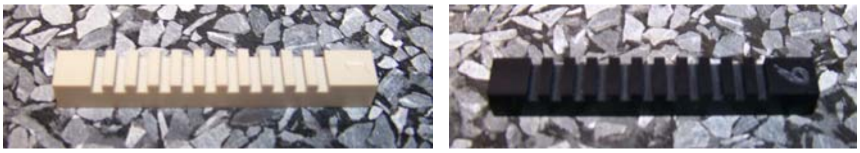

Figure 2: PEEK (left) and PPS with 40% glass (right) step gauges

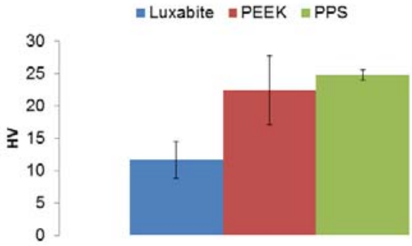

Figure 3: Hardness measurements on Luxabite, PEEK and PPS with 40% glass specimens measured with Vickers hardness test. Results are expressed in Vickers units (HV) and were obtained with a load of 10 kgf

3 Experimental investigation

The stability of the new step gauges was investigated with the same approach used for the Luxabite step gauges. The stability was monitored over a period of three months (from November 2011 to January 2012). Uni-directional and bi-directional distances were considered. Deviations with respect to the first measurements were computed together with related uncertainties (confidence level = 95%). Uncertainties were evaluated following GUM guidelines and considering the following contributes: MPE, workpiece form error, temperature effect and reproducibility (the parts were repositioned and measured again five times). In Figure 4 are displayed the outcomes for two measurands regarding PEEK step gauges: the uni-directional with nominal value = 20mm and the bi-directional, with nominal value = 22mm. The stability resulted significantly improved in comparison to Luxabite replicas, with maximum deviations below 4 µm for PEEK and limited expanded uncertainty (below 6 µm). Similar results were obtained for PPS with 40% glass and for all measurands.

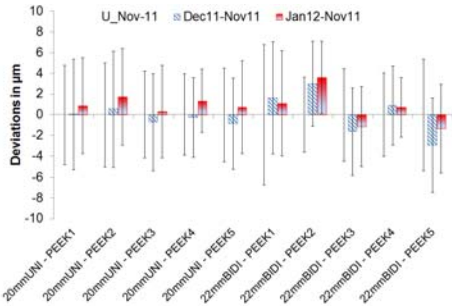

Figure 4: Deviations and expanded uncertainty for the new manufactured step gauges in PEEK in correspondence of 20mm (uni-directional) and 22 mm (bidirectional) lengths. For the first measurements (November 2011) just expanded uncertainty is reported

4 Conclusions

The work encompasses the study of stability and other mechanical properties of step gauges intended for CT scanning verification. Due to stability and surface geometry problems pointed out in previously moulded replica step gauges in Luxabite, other two plastic materials (PEEK and PPS with 40% glass) were selected on the basis of their good mechanical properties for manufacturing other step gauges through milling. Stability measurements results over 3 months and hardness measurements show a significant increase in surface geometry quality and stability in comparison to Luxabite step gauges.

Acknowledgements

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