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Measurement of micro moulded parts by Computed Tomography and comparison to optical and tactile techniques

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Abstract

This paper focuses on dimensional verification of two micro-injection moulded components, selected from actual industrial productions, using CT metrological tools. In addition to CT scanning, also a tactile Coordinate Measuring Machine (CMM) with sub-micrometer uncertainty and an Optical Coordinate Measuring Machine (OCMM) allowing fast measurements suitable for in-line quality control were employed as validation instruments. The experimental work carried out and the analysis of the results provide valuable conclusions about the advantages and drawbacks of using CT metrology in comparison with CMM and OCMM when these techniques are employed for quality control of micro moulded parts.

1 Introduction

Accuracy and time exigencies are getting tighter and tighter in the field of manufacturing engineering and smaller mechanical parts are characterized by smaller tolerances to be verified [1]. The evolution of dimensional metrology has to be capable of meeting these demands. Thereby, apart from the optimization of traditional metrology equipments, new technologies based on new measuring concepts are being developed. One of them is Computed Tomography (CT) metrology using X-rays [2-3]. CT metrology techniques are more and more applied for micro-parts geometrical verification [4], offering the advantages of non-contact, dense scanning and the capability of measuring both internal and external geometries simultaneously. On the other hand their uncertainty is still high compared to CMMs or even OCMMs.

2 Materials and Methods

Two polymer micro products were selected for this work. Both are fabricated using the micro injection moulding technology. The first product is a toggle for a hearing aid application made of liquid crystal polymer (LCP) with a part weight of 35 mg (Figure 1a). The second product is a miniaturized dog bone specimen used for micro mechanical material testing; it is made of acetal polyoxymethylene (POM) copolymer with a part weight of 35 mg (Figure 1b). Three and five specimens of the first and the second micro products respectively were measured in order to estimate the process capability and perform a comprehensive measurement uncertainty study.

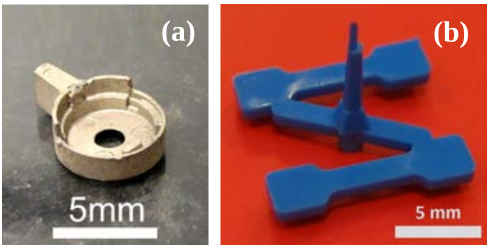

Figure 1 – Polymer micro moulded products: (a) toggle, (b) dog bone specimen.

Measurements of both internal and external geometries using the three different measuring techniques (CT, CMM, and OCMM) were compared on a verification study. Investigated measurands included part thickness, internal and external diameter, and part length (Figure 2).

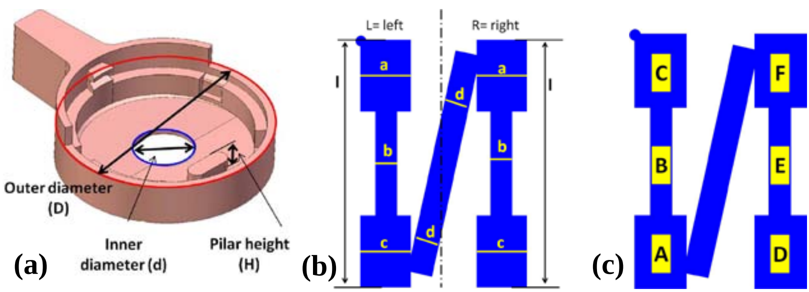

Figure 2: Dimensions measured: (a) D, d and H in toggle, (b) left and right a, b, c and d widths in dog bone, (c) thicknesses in different areas (A to F) of dog bone.

The parts where measured by two different CT machines. The first one (CT1) with an X-ray source power from 50 to 80 kV and max. resolution of 8 µm. The second one (CT2) with energy range from 40 to 130 kV and 5 µm spot size. An OCMM (MPE = 4 + L/150 µm, L in mm) allowing fast measurements and in-line quality control was employed as validation instrument. A tactile CMM with sub-micrometer uncertainty (MPE = 0.4 + L/900 µm, L in mm) was also used to measure the toggle parts.

3 Results

In Figure 3 an example of some results obtained for the dog bone 1, 2 and 3 parts are shown. Differences between the measurements taken for some of the lengths and thicknesses with CT1 and CT2 with respect to the reference values (obtained by OCMM) are shown.

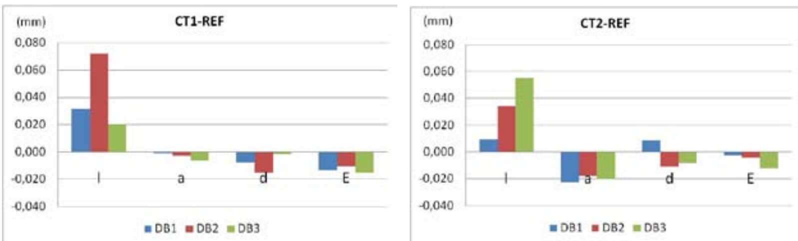

Figure 3: Differences between the values measured by CT1 and the reference values (left) and CT2 and the reference values (right) for l left, a left, d left and thickness in E for parts dog bone 1, 2 and 3.

The magnitude of deviations when measuring with CT technology is always smaller than 1% the reference dimension in the results obtained both for dog bone specimens and toggle parts.

Apart from the influence of machines' errors and measuring procedure used, other sources of uncertainty can explain the differences found. The significant form errors of the samples lead to different measurand definitions and therefore different measuring systems give different measuring results. This influence has been tried to minimize by using a common measurement procedure. However, some differences still remain (i.e. OCMM is able to measure the distance between edges on the thickness direction and not distance between planes). For this reason, further comparison with tactile CMM is currently ongoing. Dimensional instability of the material, mainly taking into account that the specimens are made of plastic, is an additional source of uncertainty. All the parts were measured by a reference machine before and after their circulation around the two CT machines (for about 6 months). The results show stability better than 5 µm for the toggle dimensions and better than 20 µm for the dog bone dimensions.

4 Conclusions

The analysis of the results show the feasibility of CT measuring techniques for a complete quality control of 3D micro moulded parts. Tactile measurements are often not suitable for these parts due to their soft substrate surface. In these cases, CT techniques are an excellent alternative due to their non-contact measuring capabilities and their capability to provide morphological information such as suctions (i.e. valleys) on the parts' surfaces and voids inside the mouldings. Their ability of collecting very complete point clouds independently from material properties and form errors is another advantage of CT in contrast to other non-contact measuring techniques such as OCMMs. However, in order to improve the uncertainty of the results, correction factors still have to be applied to the measurements.

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