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Comparison of measurements from optical CMM and focus-variation microscope of a µPIM mechanical part

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Abstract

Two sets of 5 green and 5 sintered mechanical parts, manufactured by micro powder injection moulding (µPIM), were measured using an optical coordinate measuring machine (OCMM) and a focus-variation microscope (FVM). The examined features of size, including diameter, radii and distances, span in the range of (10^{-1}–10^{1}) mm. Comparing the corresponding measurements from the two instruments, a relative maximum deviation of 8 % was found for the linear dimensions of the green parts and a relative maximum deviation of 6 % for the ones of the sintered parts. The maximum relative deviation of the radii was 17 % for the green parts and 30 % for the sintered parts (relative deviations have been evaluated considering focus-variation measurements as reference).
OCMM showed some problems in the detection of the smallest dimensional features (above all radii) where the presence of defects on the edges, quite typical for parts produced by µPIM, was particular critical for the measurements.
The extraction of results obtained from FVM was less critical because performed with a dedicated post-processing software which allowed to better define the measured dimensions. Furthermore, the chance to measure other geometrical features, such as surface texture and flatness, may depict FVM measurements as more attractive. However, measurements should be suitable for in-line quality control, in a production environment, where fast cycle time is required and measuring times are more compatible to those of the OCMM.

Keywords: Micro Powder Injection Moulding (µPIM), Quality Assurance, Focus-variation Microscope, Optical CMM

1. Introduction

Quality assurance for micro manufactured parts is a key issue for defect-free production [1]. The selection of the measuring instrument to be used for inspecting the parts is a fundamental aspect for the success of the quality assurance operations. The choice becomes especially difficult when multiscale specimens are under evaluation, i.e., when the features of size to be measured are close to one end of the operating range of a measuring technology.

This work aims to highlight challenges in the choice of a measuring instrument in an industrial environment.

In this view, an optical coordinate measuring machine (OCMM), commonly used in an industrial environment, was opposed to a focus variation microscope (FVM), suitable for laboratory use. A study case served for emphasising related pros and cons: 5 green and 5 sintered parts of a micro mechanical component, manufactured by micro powder injection moulding (µPIM) [2], have been measured and successively compared using the two instruments.

Examples of both green and sintered parts are in Fig. 1. The nominal values of the features of size that have been considered are instead given in Fig. 2. They refer to the dimensions intended for the sintered parts.

2. Measurement and post-processing

A set of fourteen dimensions were measured including one diameter, eight radii and five lengths. The values were in the range of (10^{-1}–10^{1}) mm.

The OCMM was DeMeet 220 with magnification 2×, lateral resolution 4 µm.

The FVM used was Alicona InfiniteFocus® with magnification 5×, vertical resolution 500 nm, lateral resolution 7 µm.

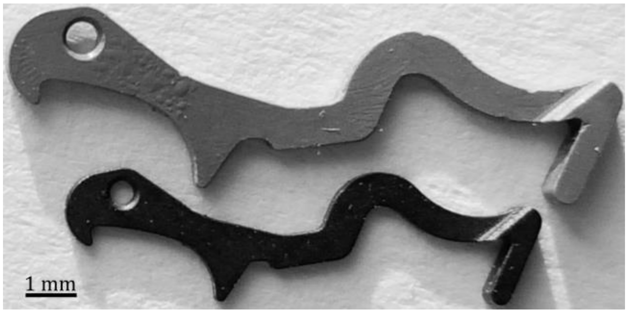

Figure 1. Micro mechanical components produced by µPIM. Top: example of green part. Bottom: example of sintered part.

Results related to OCMM did not need post-processing since the instrument is equipped with a software [3] which directly provide the values related to the measurements. Conversely, the acquired images using FVM were successively processed by [4]. The software's routine for contour fitting was used to extract the measurements of the features in the *xy*-plane.

It should be noted that the specimens contained burrs and splinters which made sometime difficult to properly detect their contours. Hence, in those cases, the faults in the edge detection resulted in a larger variability of the values among the specimens and, consequentially, in a larger evaluated uncertainty.

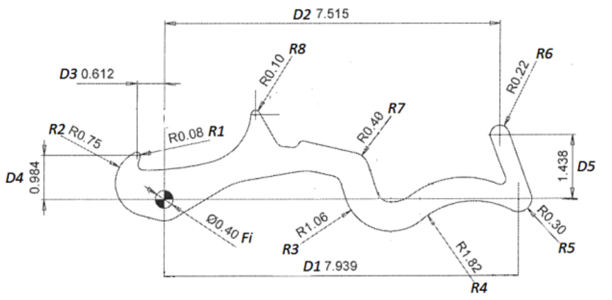

Figure 2. Scheme of micro mechanical component with the nominal values of the examined features of size. Dimensions intended for the sintered parts (final product).

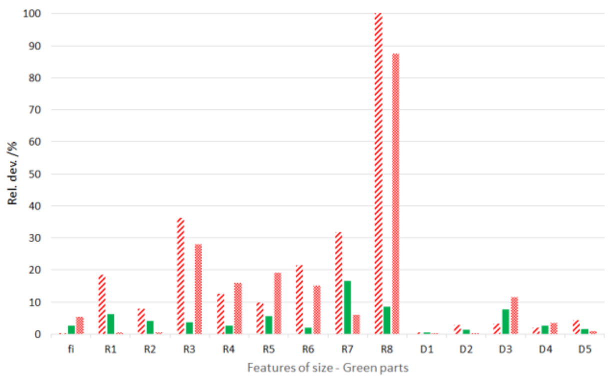

Figure 3. Relative deviations between the measurements of the green parts performed by OCMM and FVM. FVM is considered as reference. Considering the expanded uncertainty U, the red-dashed columns () are the relative deviations between the lower limits $d_{OCMM} - U$ and $d_{FVM} - U$; while, the red-dotted columns () are the relative deviations between the upper limits $d_{OCMM} + U$ and $d_{FVM} + U$ (see Eq 1).

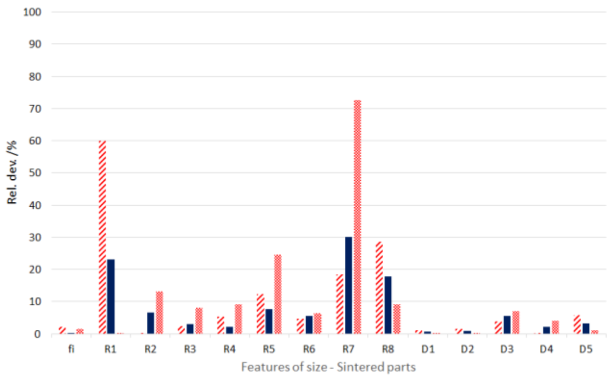

Figure 4. Relative deviations between the measurements of the sintered parts performed by OCMM and FVM. FVM is considered as reference. Considering the expanded uncertainty U, the red-dashed columns () are the relative deviations between the lower limits $d_{OCMM} - U$ and $d_{FVM} - U$; while, the red-dotted columns () are the relative deviations between the upper limits $d_{OCMM} + U$ and $d_{FVM} + U$ (see Eq 1).

3. Results and uncertainty

The results of the comparison are expressed as relative deviations between the measurements performed by OCMM and FVM, i.e.:

$$\Delta d = \left| \frac{d_{OCMM} - d_{FVM}}{d_{FVM}} \right| \times 100 \qquad (1)$$

being d the generic dimension.

FVM measurements were considered as reference because they showed a lower average uncertainty (the indication was given by a quadratic average of the uncertainties related to all the measured dimensions).

The expanded uncertainty U was evaluated according to [5] for both instruments' measurements. The results are summarised in Fig. 3 for the green parts and in Fig. 4 for the sintered parts. In the figures the relative deviations between the lower limits $d_{OCMM} - U$, $d_{FVM} - U$ and the upper limits $d_{OCMM} + U$, $d_{FVM} + U$ are also given.

Measurements of the green parts showed maximum values of relative deviations of 17 % for radii and 8 % for linear dimensions. The minimum relative deviations observed were 2 % for radii and below 1 % for linear dimensions. Measurements of the sintered parts have maximum values of relative deviations of 30 % for radii and 6 % for linear dimensions. The minimum relative deviations observed are below 1 % for both.

Regarding the expanded uncertainty evaluated, it leaded to even larger relative deviations between the two sets of measurements when considering the limits of the corresponding uncertainty intervals. As already observed, the difficulties in the edge detection of some specimens, due to the presence of defects, increased the variability of the values. This affected above all the measurements of the green parts and the ones performed with OCMM.

4. Conclusions

The measurements of the smallest dimensional features (above all radii) by OCMM were particular critical due to the presence of defects on the edges, quite typical for parts produced by µPIM. This tendency was also noted for sintered parts. The reduction of the dimensions after the sintering process resulted in increased relative deviations between the measurements from the two different instruments.

Moreover, regarding OCMM measurements, radii were measured directly. Linear dimensions were instead measured as segments using the centres of the circles (radii) as inputs. In this way, relative deviations of linear dimensions might have increased by errors propagated from the inputs.

The extraction of results obtained from FVM, which was performed with a dedicated post-processing software [4], allowed to better define the measured dimensions. In addition, it could also be suitable for measuring other geometrical features, such as surface texture and flatness. Nevertheless, measurements by FVM and its post-processing need to be optimised to be suitable for industrial quality control, whereas measuring and processing times are more compatible to those of OCMM.

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