Process characterisation of soft-tooled micro-injection moulding through X-ray computed tomography and laser-scanning-confocal microscopy

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29.11.2023 – Euspen SIG: Micro/Nano Manufacturing, Ilmenau, Germany

WMG THE UNIVERSITY OF WARWICK

CATAPULT High Value Manufacturing

NXCT National X-Ray Computed Tomography

Content

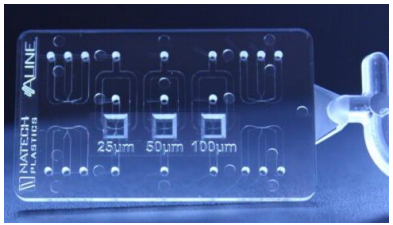
- Research background – soft-tooling, X-ray CT,
- Test object & tool design, micro-injection moulding,
- XCT and laser-scanning confocal data analysis/comparison,
- XCT visualisation & overlays,
- Summary and future work.

RESEARCH BACKGROUND & MOTIVATION

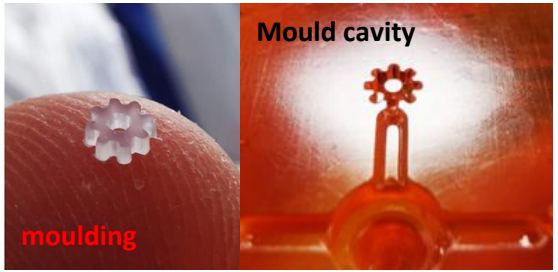
Research background & motivation

- Development soft-tooled micro-injection moulding for rapid prototyping,
- Quality assessment: advanced microscopy (3D but limited) – XCT can be alternative,
- Soft-tooled moulding: have many process variables – a good case study for XCT,
- **Key aim:** creating predictive process modelling and utilisation of XCT for micro-manufacturing.

www.medicalmoulds.com



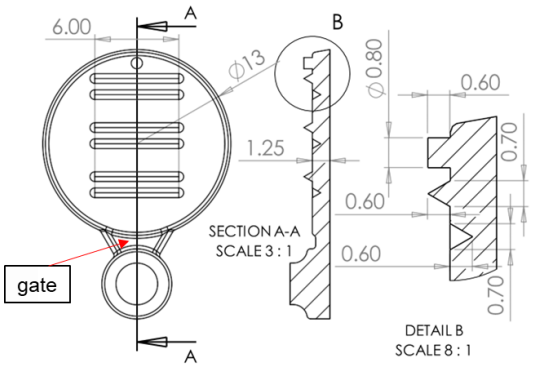
https://www.natechplastics.com/



3 mm gear component

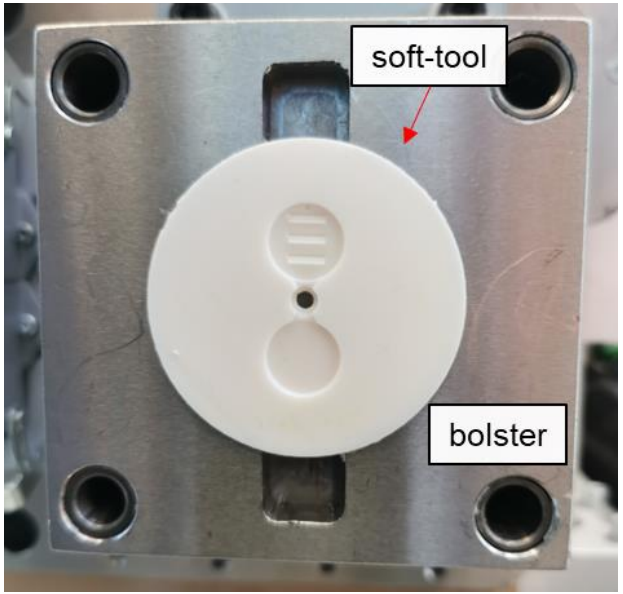
TEST OBJECT DESIGN AND MICRO-INJECTION MOULDING

Test object design



Object design

Moulded object

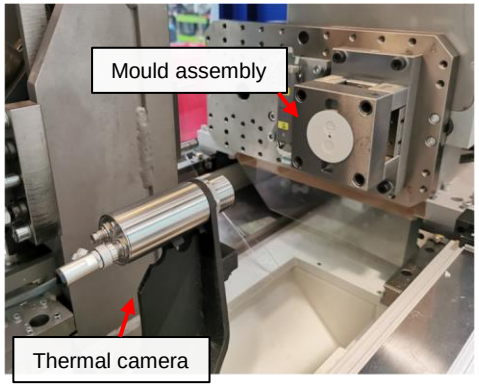


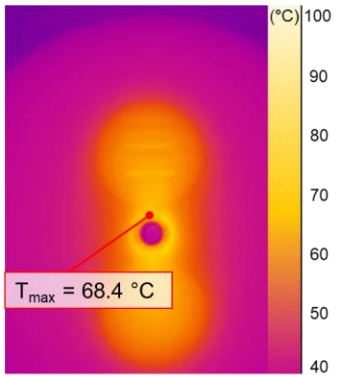
Mould assembly

- Ridges and round features allowed specific measurements,
- Material jetting was used for making the soft mould insert.

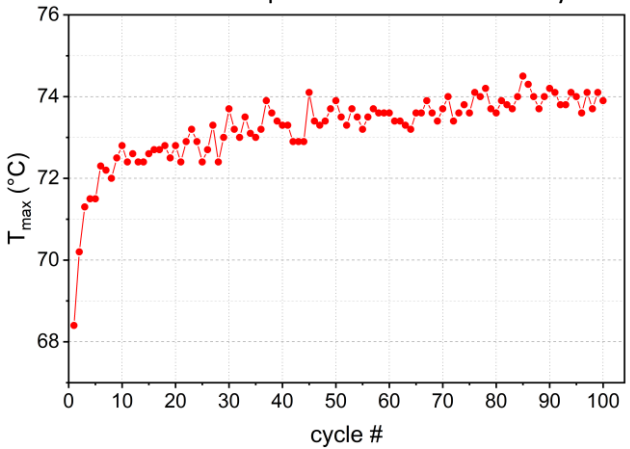
Micro-injection moulding

Melt temperature (°C)	Injection velocity (mm/s)	Switch-over pressure (bar)	Packing pressure (bar)	Cycle time (s)	Shot size (cm^3)
190	200	150	200	30	0.445





Max. surface temperature evolution over cycles

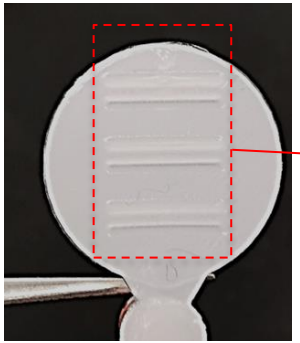


- Made 100 parts back-to-back (soft-tool heated up),
- Slight short shots (~99% filling)
- Used polypropylene,
- No mould cooling or heating used.
- T_{max} : replication – viscosity indicator.

XCT and laser scanning confocal microscopy (LSCM)

Tescan UniTOM XL

- XCT and LSCM data captured for 19 samples (1-10, and 10, 20, 30, 40 ,50 ,60, 70 , 80, 90 and 100th.



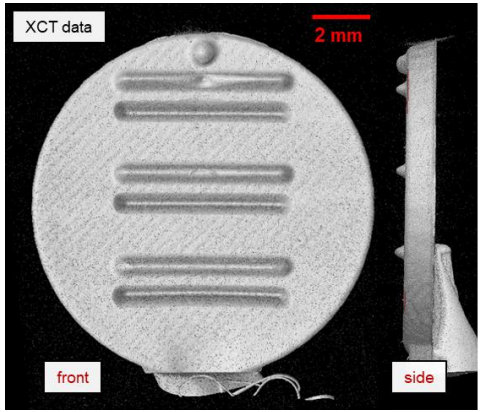
LEXT – OLS5000, Olympus
- 10x objective lens
- 7 x 10.5 mm area

XCT Parameter	Value & units
Exposure voltage	80 kV
Exposure power	15 W
Exposure time	81 ms
Voxel size	10 µm
# of projections	2279
Total scan time	18 minutes

General comparison of XCT and LSCM:

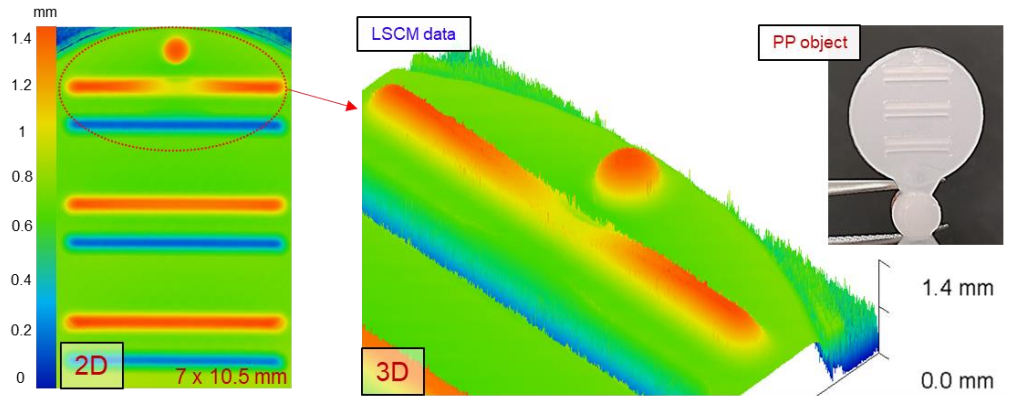
Feature	XCT	LSCM
Acquisition area/volume	Full 3D	(only ~40% of the surface topography)
Total Scan time	18 mins	20 mins
Height resolution in z-axis	10 µm	0.1 µm

XCT and laser scanning confocal microscopy (LSCM)



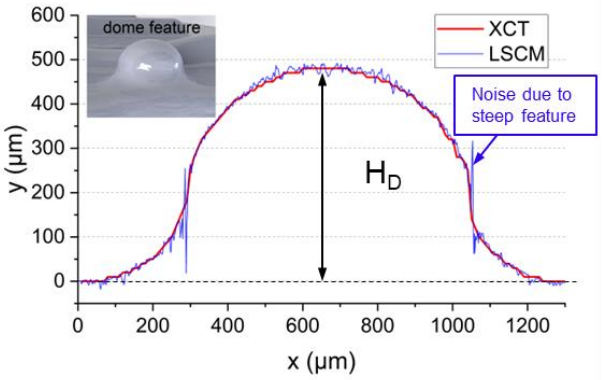
XCT

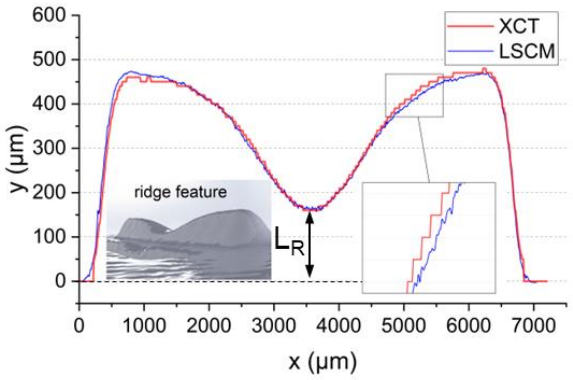
LSCM

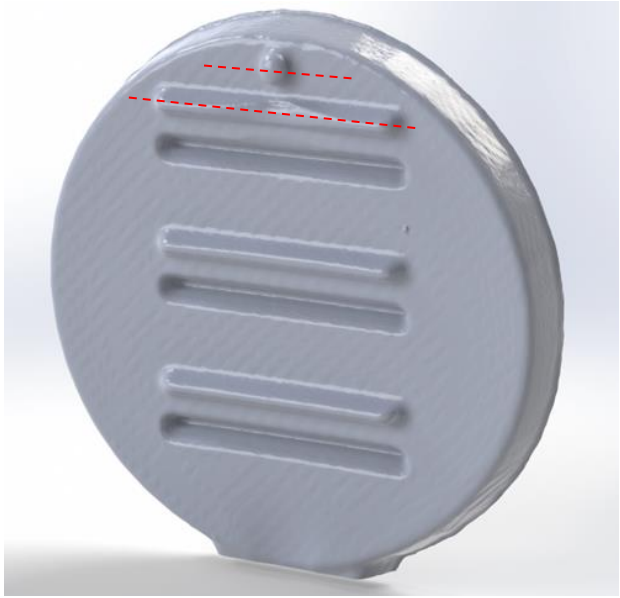


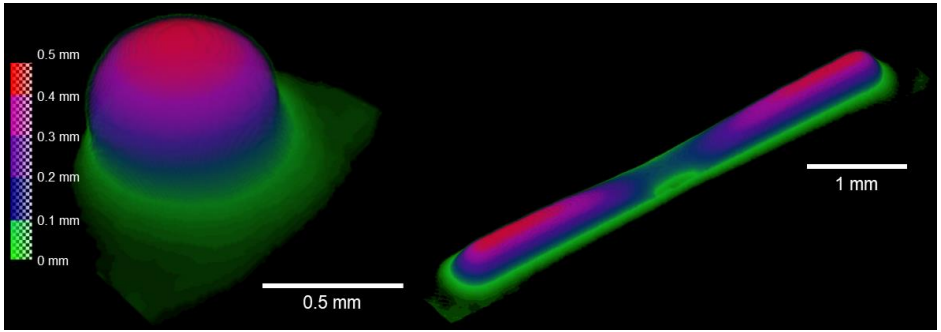
XCT AND LASER-SCANNING CONFOCAL DATA COMPARISON

XCT and LSCM data comparison



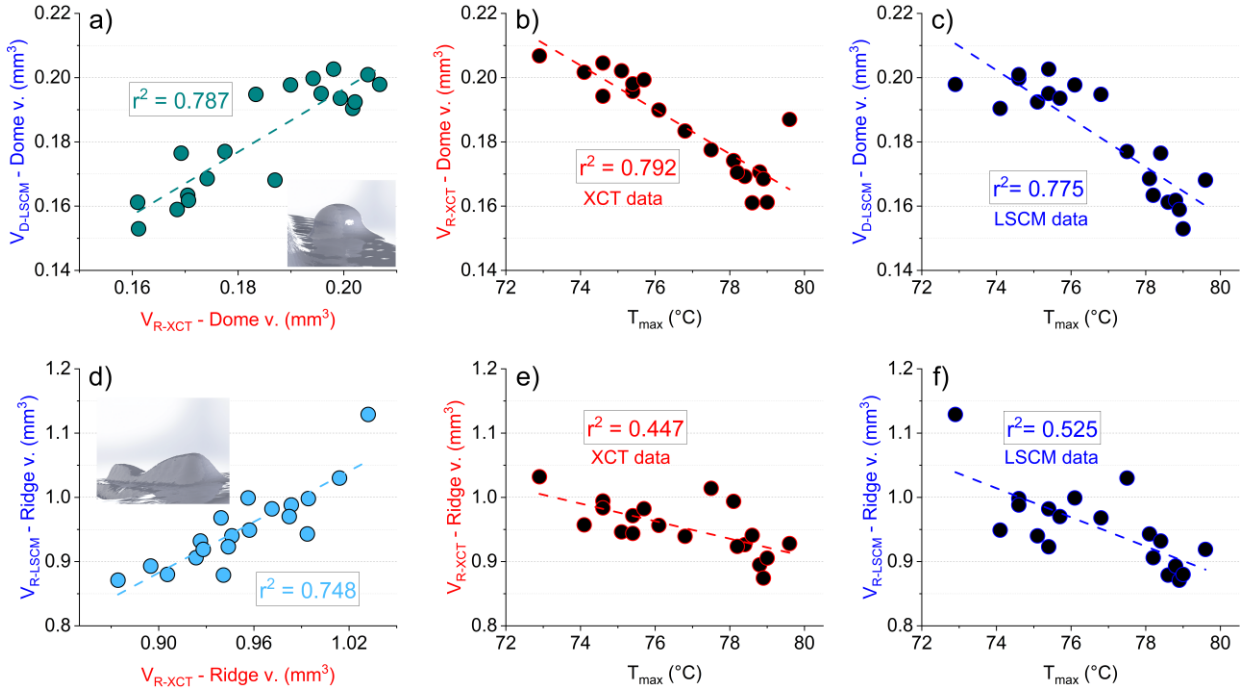






Volumetric measurements for the dome and the ridge features calculated for XCT and LSCM.

XCT and LSCM data comparison



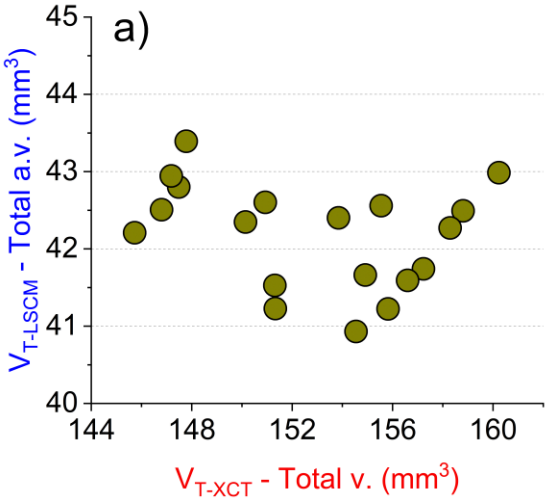
Approach:

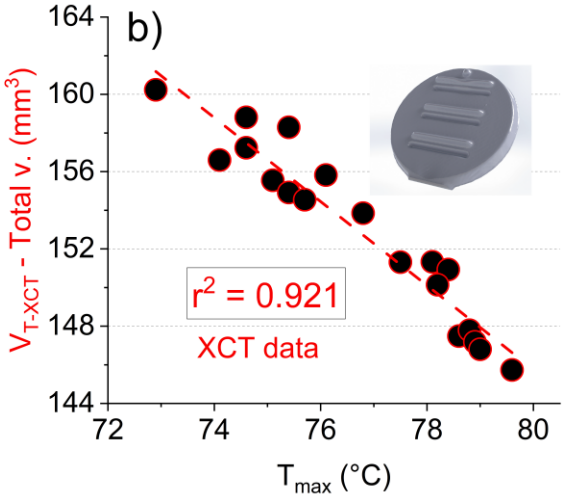
1. XCT – LSCM comparison,
2. Validation against T_{max}.

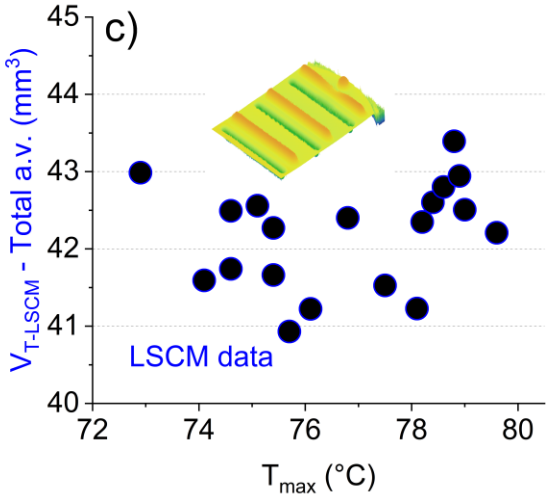
- Methods vary: a) and d).
- XCT for dome, marginally better.
- Ridge feature: difficult plane selection.

A good first step for showing XCT's capability.

XCT and LSCM data comparison

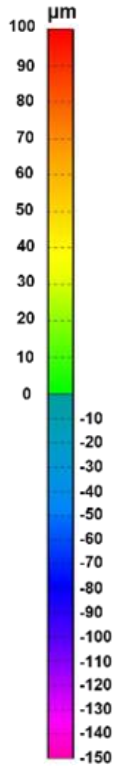




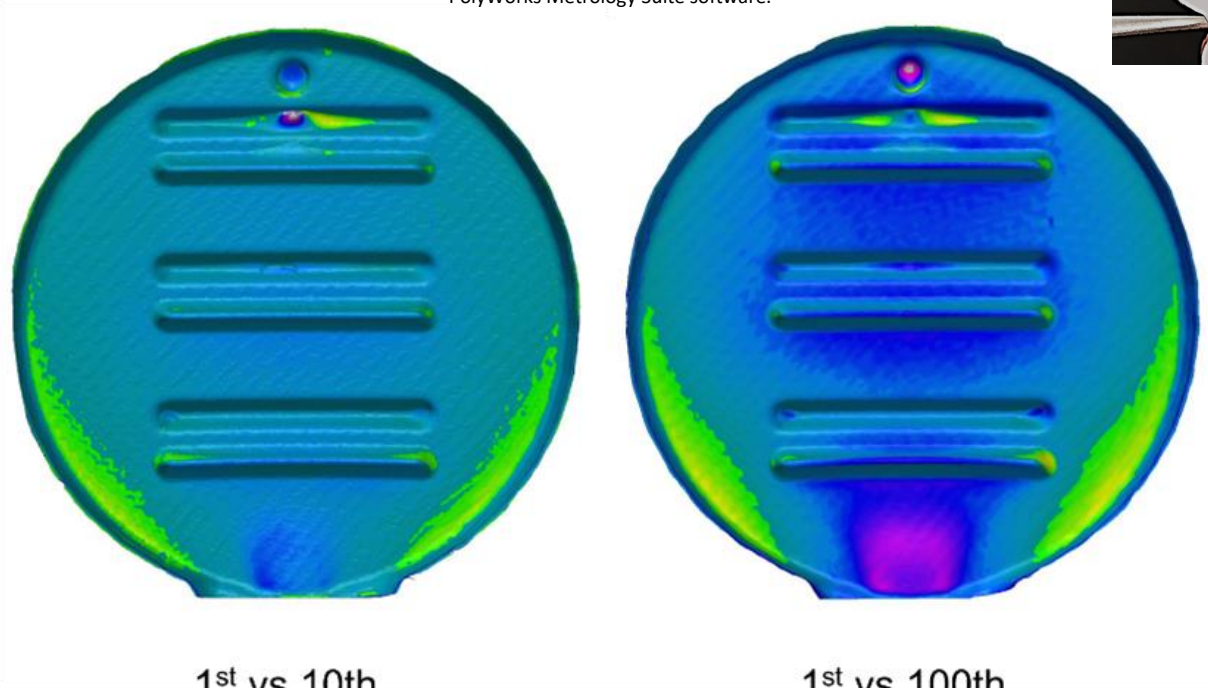


- No correlation in measurement comparison,
- XCT resulted in **92.1% accuracy** in filling prediction,
- LSCM volume measurement: prone to plane selection, unrepeatable measurements.
- **Overlay comparisons using XCT?**

XCT overlays for detecting process variations



PolyWorks Metrology Suite software.

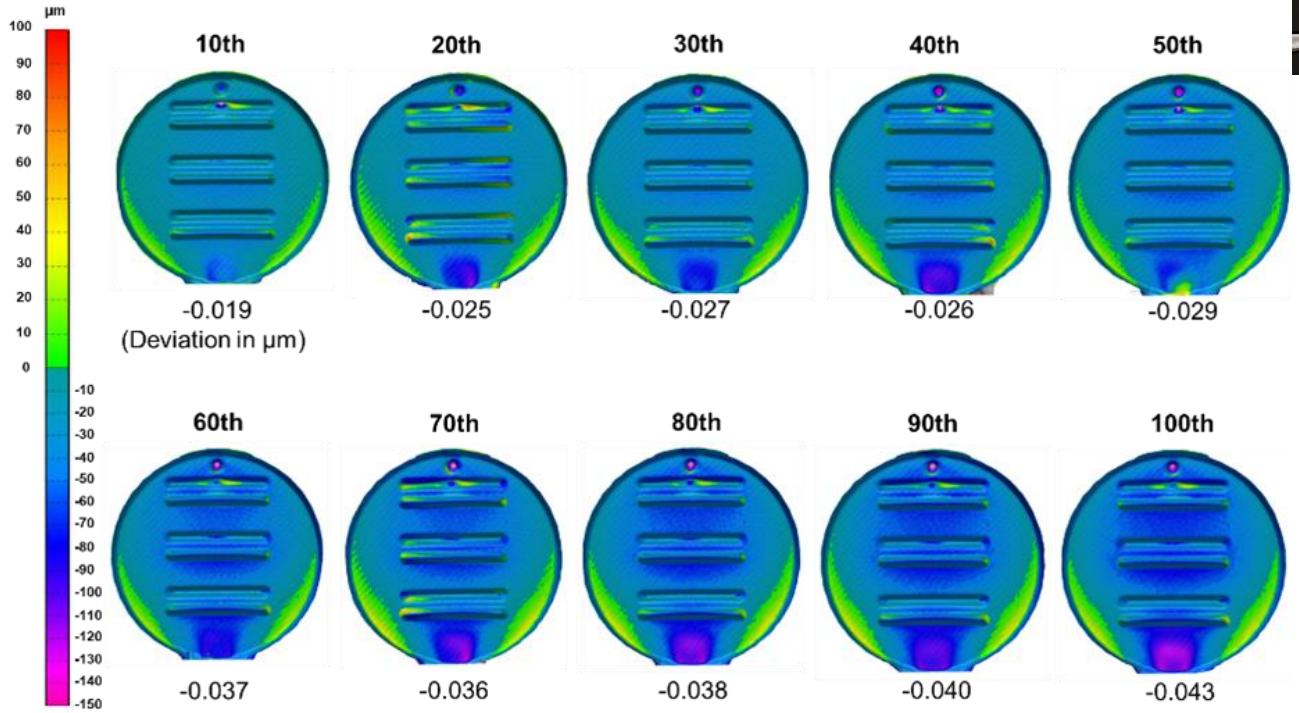


1st vs 10th

1st vs 100th

- STL overlays – 1st = pristine.
- Standard best-fit method.
- Soft-tool deformation can be visualised/quantified.
- ~150-micron deformation near the gate.

XCT overlays for detecting process variations



- Progressive soft-tool deformation visualised,
- Can be an effective method for characterising 3D printed soft-tool suitability,
- ~15% decrease in cavity volume,
- 10-micron voxel size – but in 3D.

SUMMARY AND FUTURE WORK

Summary and future work

- XCT superior – no optical limitations, steep walls etc.,
- Even 10-micron voxel scans proved to be useful,
- 92.1% accuracy: predictive quality monitoring,
- Overlays allowed 3D visualisation of soft-tool deformation.

Future work:

- Soft-tools can be annealed – improvements can be visualised,
- Pushing 92.1% accuracy towards %100 – increase resolution.