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Effect of metal artifacts in polymer macro dimensional 3D evaluation by XCT in multi material parts

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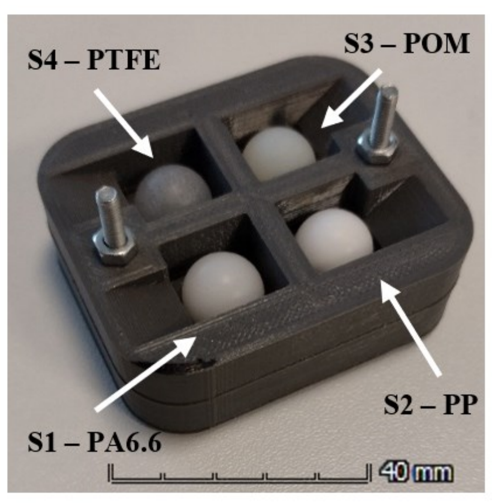
Abstract

X-Ray Computed tomography (XCT) measurements are highly influenced by the material of the object measured [1]. XCT settings vary depending on the attenuation coefficient of the material, an intrincsic property directly linked to its density: higher density materials require higher energy (voltage, current, etc) for an optimal X-ray penetration. In multi-material parts, it becomes more challenging, as settings should be optimised for all materials [2-4]. Metal-polymer combination is very common in industrial assemblies, and due to the high difference in density, XCT characterisation of polymers could be the most important issue. In this study, the distortions caused by the presence of metal in the dimensional evaluation of polymeric precision spheres is presented. An ad hoc test object is designed with 4 scenarios planned, increasing the amount of metal present. Results show a correlation between dimensional deviations and metal presence. Form error of the spheres is the highest affected feature, as it is surface determination dependant and, therefore, more sensible to the noise and artifacts produced by metals.

Design and materials

- 4 precision polymeric spheres: Nylon (PA6.6), Polypropylene (PP), POM, Teflon (PTFE).
- 4 scenarios: No metal (NM), steel inserts (Scr), aluminium covers (Al), steel covers (St).
- General dimensions: 55 x 40 x 17 mm. Spheres diameter: 12 mm.
- Al cover thickness: 3.85 mm. St cover thickness: 2 mm.

a)



b)

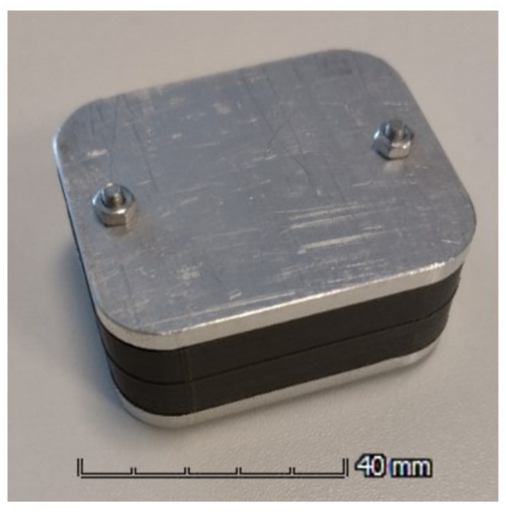


Figure 1. Test object. a) Precision spheres distribution. b) Assembly with metallic coverings.

Material	Density [g/cm^3]
PP	0.87
PA6.6	1.11
POM	1.37
PTFE	2.16
Al	2.70
Steel	7.85

Table 1. Density of materials.

Methodology

- XCT settings adjusted for each scenario (Table 2).
- CMM device: Zeiss PMC-876 CNC.
- XCT device: Zeiss Metrotom 1500/225 kV → Software VG Studio Max 3.4.2.
- Simulations with same XCT settings. → Software aRTist 2.12.

XCT Settings	NM	Scr	Al	St
Voltage [kV]	140	140	195	175
Current [μA]	410	410	294	328
Phisical filter	Al 2 mm	Al 2 mm	Cu 0.75 mm	Cu 0.75 mm
Nº of projections	1500	1500	1500	1500
Exposure time [ms]	500	500	500	500
Voxel size [μm]	47.5	47.5	47.5	47.5

Table 2. XCT Settings.

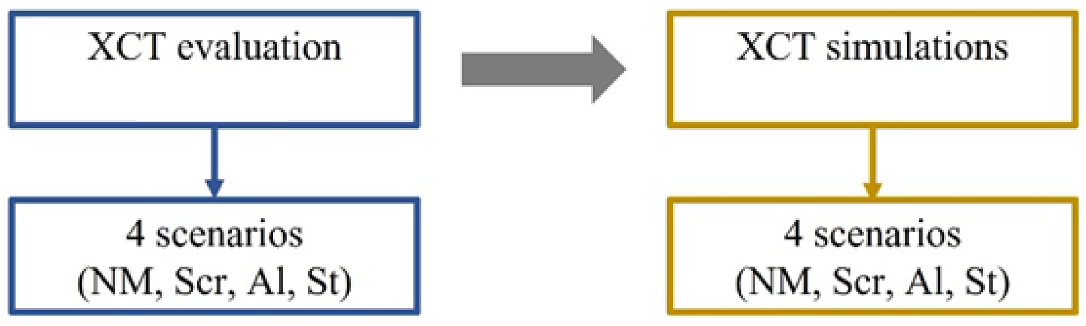


Figure 2. Methodology workflow.

Results and discussion

Surface determination method

- First general surface determination (SD) → ISO 50, advanced (multi material), search distance = 4 voxels.
- Local surface determination for spheres' region of interest (ROI) → Same SD method as general SD.

Material differentiation

- Peaks of each polymer/sphere are more clearly differentiated in scenarios with less or no metal (see Fig. 3).
- In St scenario, differentiation is not possible (peaks fused).

Dimensional results

- Form error increases exponentially for scenarios with high amount of metal (Fig. 4).
- Trend is followed for diameters and distances; however, effect is lower (Fig. 5).
- Similar results obtained both in simulations and real tomographies.

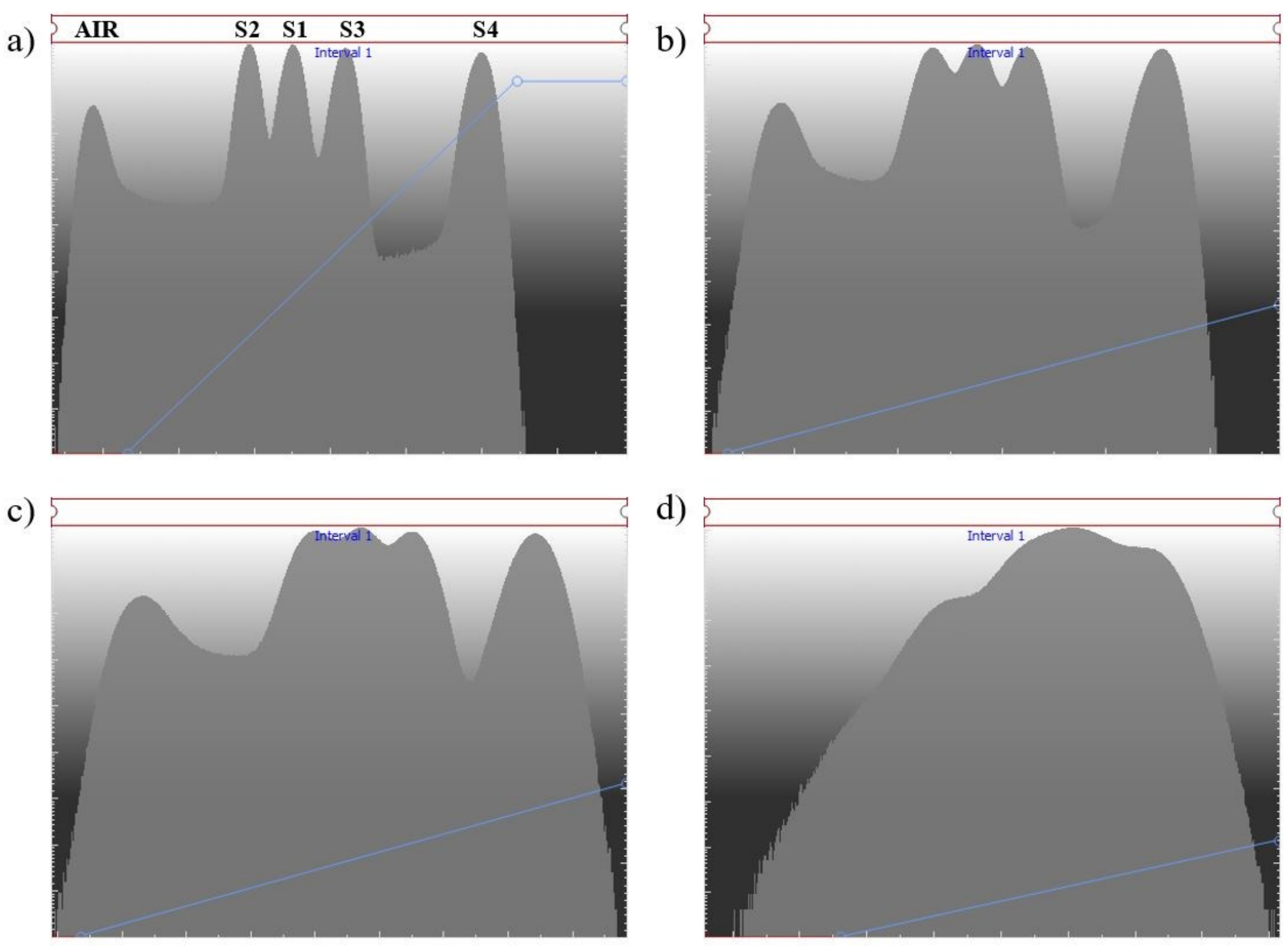


Figure 3. Gray values histograms in XCT. a) NM. b) Scr. c) Al. d) St.

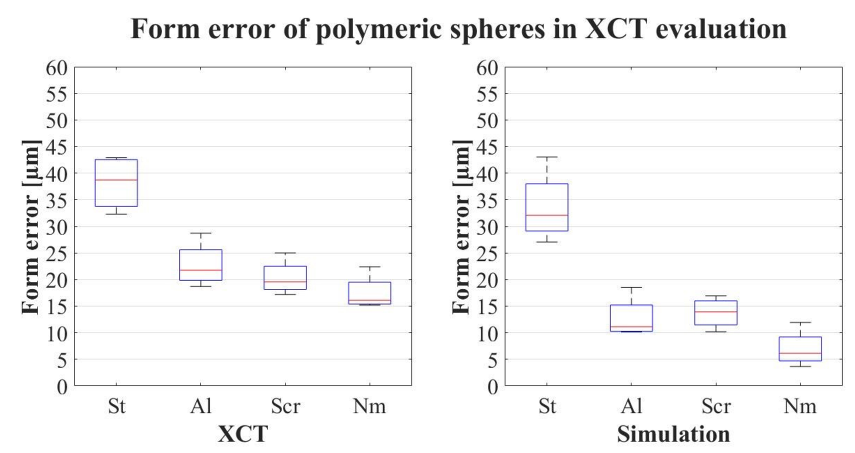


Figure 4. Absolute form error mean values.

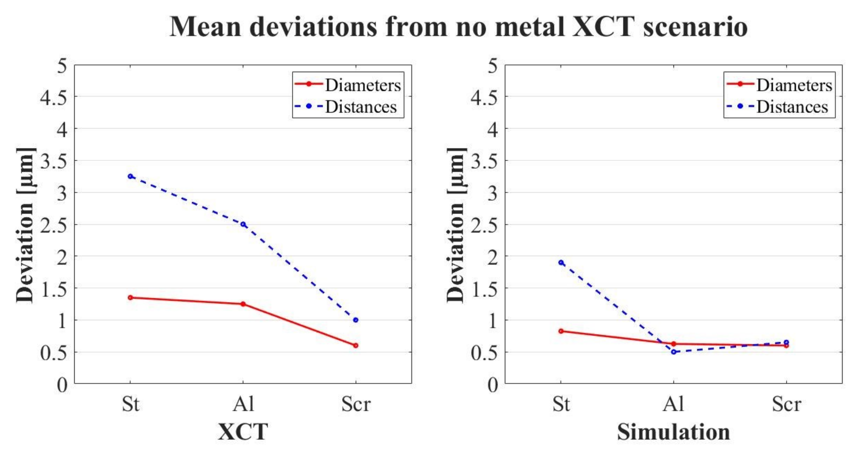


Figure 5. Diameters and distances mean deviations from NM scenario.

Conclusions and future work

- Increasing the amount of metal in the assembly makes more difficult the characterisation of the polymeric features → more noise and artifacts, despite the parameters are optimised for each scenario.
- Steel affection is higher than aluminium even in smaller quantities → higher density difference with polymers.
- Correlation between amount of metal and distortion in dimensional evaluation, mainly in form error → more surface determination dependant, therefore more sensible to noise.
- Diameters and dimensions are less influenced by surface determination, and more robust.
- Future work: evaluate other types of geometries, amplify the experiment to find generalities applicable to a more range of cases.

References

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