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Additive manufacturing process assessment framework for x-ray computed tomography derived measurement

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Abstract

Additive Manufacturing (AM) enables the creation of complex, previously unattainable geometries, unlocking newfound potential across aerospace, biomedical, and industrial sectors. However, for safety-critical or highly engineered parts, this design freedom can only be realised if complemented by robust internal inspection and dimensional verification. X-ray Computed Tomography (XCT) has emerged as a critical enabler, offering volumetric, non-destructive imaging capable of detecting porosity, verifying dimensional conformity, and supporting analysis of functional lattice and multi-material structures.

Despite significant advancements in XCT, key barriers remain that hinder its routine deployment in AM metrology. Measurand-specific probing errors and inconsistencies in data processing and interpretation arise from interrelated factors of this complex measurement process. Guidelines for traceable XCT measurements in AM remain fragmented, lacking a unifying artefact-based approach. Without scalable, standardised measurand-specific calibration, XCT results in AM are often qualitative or validated case-by-case, obstructing traceability, inhibiting experimental translation, and inherently inflating R&D costs. To address these challenges, we propose a metrological framework built around an extensible family of customisable modular artefacts designed to supply 'ground truth' in diverse geometric, material, and surface characteristics relevant to AM. The artefacts are not principally intended to mimic part geometry but rather provide a vehicle to apply traceable metrology to AM process validation and optimisation. The framework promotes methodological standardisation through generalised analysis tools, formalised methods of data quality assurance and guidance on experimental design and relevant metrological principles and methods. This will promote the accumulation of knowledge towards best practice and ultimately reduce the cost burden in both industrial production and research-driven applications.

In addition to the modular artefact concept, this project is an ambitious effort to capture constraints in AM requirements and XCT measurement processes, in addition to calibration and manufacturability of reference artefacts. These constraints capture the necessary trade-offs which must be considered in any experimental design. The aim is to provide a standardised toolkit to guide qualification of XCT-derived measurement for AM workflows, thereby accelerating AM adoption.

Additive Manufacturing, X-ray Computed Tomography, metrology, traceability