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Comparison of Three Measurement Modalities for 3D Characterization of Manufactured Features and Process-Induced Porosity in Additively Manufactured Titanium Alloy Parts

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ABSTRACT

This paper details an investigation into X-ray computed tomography (CT) data acquisition, reconstruction, and analysis, comparing extracted data with mechanical polishing serial sectioning and optical inspection data. The goal is to report on the systematic limitations of each measurement modality, comparing and contrasting the advantages and disadvantages of each method for 3-dimensional analysis of intentional internal features and unintentional internal porosity.

A principal advantage of additive manufacturing (AM) techniques is creating parts that cannot be made using conventional subtractive techniques, such as milling or turning. Accurately characterizing manufactured internal features and defects within complex AM components is vital for many applications, including critical aerospace components and assemblies. With the rapid development of AM techniques, non-destructive inspection techniques have become increasingly important.

Parts manufactured using conventional subtractive manufacturing techniques can generally be inspected using instruments following the machining tool paths to verify dimensions and surface finish. Parts designed for AM manufacture are not constrained by tool-path limitations and often internal features cannot be non-destructively inspected using conventional inspection techniques (CMMs, micrometers, surface profilometers for example). X-ray CT inspection is not limited by these tool-path restrictions and can be used to image the often critical internal features of complex AM components.

A Ti5553 titanium alloy test object was additively manufactured using laser powder bed fusion. The nominal powder size for this object was 15-45 µm and the build parameters were set to produce approximately 2.5% process-induced bulk porosity. The design includes multiple machined features, several of a dimension-scale designed to challenge X-ray CT resolution limits. A cap, also manufactured from Ti5553, was assembled onto the test object before X-ray CT scanning. This cap functioned to embed the machined features, enabling CT porosity analysis to be performed on the now effectively internal machined features.

Keywords: X-ray CT, Mechanical Polishing Serial Sectioning, Optical Surface Profiler, Porosity, Registration, Titanium Alloy, Additive Manufacturing.

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