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Deep Learning workflows for high-precision dimensional metrology using X-ray Computed Tomography

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Abstract

Industrial X-ray CT has evolved into a popular solution in modern quality control applications, such as in geometric dimensioning and tolerancing of metallic components. In a typical CT metrology workflow, a surface is first determined from a CT reconstruction. However, the total exposure time can be dramatically long to achieve adequate signal-to-noise (SNR) ratio to accurately determine the surface for high-precision dimensional metrology. Hence, the applicability of this tool to in-line (or online) metrology can be challenging for mm-sized metallic components (e.g., automotive fuel injectors) demanding high (< 5 μm) surface resolution due to low photons/pixel ratio.

Here, we evaluate two DL-based software packages – CTSegNet and DeepRecon for reducing scanning time for measurements of the internal orifices (diameter of ~175 $\boldsymbol{\mu m}$) of a steel fuel injector in a Zeiss Versa 620. CTSegNet was developed by the first author (A. Tekawade) at Argonne National Laboratory for direct surface determination from CT scan volumes. DeepRecon was developed by ZEISS as a reconstruction engine for denoising volumes obtained from low-dose scans. The main purpose of this paper is to analyze potential reductions in scanning time when DL-based workflows are used to augment image-quality. A research fuel injector was scanned using a ZEISS Versa 620 by acquiring a total of 3600 X-ray projections with 6 seconds exposure per projection (total 6 hours). The data was reconstructed using equally spaced subsets of those projections (e.g., 2X, 4X, 6X, 8X, 10X; where 4X means 900 projections) to mimic reduced scan time. Each subset was reconstructed using DeepRecon Pro (DRPro, the latest version of DeepRecon) as well as a traditional Feldkamp–Davis–Kress (FDK) reconstruction algorithm and then thresholded to determine the surface. The data reconstructed by FDK was directly binarized using CTSegNet. We conclude that variations in measurement accuracy of hole diameter and cylindricity are expected to be in the order of 2 μm or less when using DRPro and CTSegNet with a 10X throughput factor. In contrast the deviations produced by the FDK method are larger than 2 μm and produce more noisy data, showing that DL-based workflows can increase the throughput of CT acquisition while minimizing accuracy loss in dimensional data.