METROLOGY CHALLENGES OF PARTS PRODUCED USING ADDITIVE MANUFACTURING

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ABSTRACT

Additive manufacturing (AM) processes provide a variety of optimization opportunities using the enlarged space of designs previously inconceivable using traditional subtractive manufacturing methods. Along with these design freedoms come significant complications for the metrology of parts produced using AM, as increases in design complexity may make traditional measurement of many features prohibitively time-consuming, difficult, or even impossible to perform non-destructively. Surface mapping using touch probe or 3D scanning methods is suitable for the measurement of complex surfaces and simple topologies, but provide limited utility in assessing internal structures or other features hidden by more complex topologies where an interior structure is obscured. An example of such internal structure is illustrated in Figure 1, showing a view of infill structures which are not externally visible.

X-ray computed tomography (CT) provides a more robust method for the non-destructive evaluation of both internal and external surfaces by providing a voxel-based volumetric map of an effective radiographic absorption coefficient, which may be used to reconstruct the object surface even in the case of multi-material objects [1,2,3]. The absorption map for a DMLS dogbone can be seen in Figure 2, prior to any surface reconstruction.

Surface reconstruction provides a means for assessing the dimensioning and tolerance over the entire design (internal and external) using a direct comparison applied between the reconstruction and the original CAD model used to manufacture the reconstructed object. Surface reconstructions also provide a basis for other techniques traditionally applied to CT data (defect analysis, part-to-part comparisons, porosity analysis, reverse engineering, etc.) which are often relevant to the qualification of AM parts and processes more broadly.

FIGURE 1. Cross section view of printed polymer herringbone gear showing interior infill support structures.

FIGURE 2. DMLS dogbone CT data prior to surface reconstruction, with residual support structure underneath.
This work applies several of these analytical X-ray CT approaches for the inspection and qualification of polymer and metal objects created using a variety of AM processes including direct metal laser ‘sintering’ (DMLS), laser engineered net shaping (LENS), and fused filament fabrication (FFF), with a particular emphasis on defect detection, density/porosity analysis and geometric dimensioning using surface reconstruction comparisons, as shown in Figure 3. The range of applicability of this technology, as well as its limitations and potential for use in the inspection of AM parts will be discussed.

![Surface comparison of FDM/FFF herringbone gear. The peaks and troughs of the teeth can be seen to deviate more than 0.07mm from the expected surface defined by the model.](image)

**FIGURE 3.** Surface comparison of FDM/FFF herringbone gear. The peaks and troughs of the teeth can be seen to deviate more than 0.07mm from the expected surface defined by the model.

REFERENCES

