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Comparison of Different Additive Manufacturing Methods Using Optimized Computed Tomography

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Abstract

Additive manufacturing (AM) allows for fast fabrication of three dimensional objects with the possibility of use of considerably less resources than would be the case in traditional manufacturing. AM is a fast and cost effective method which boasts the ability to produce components with a previously unachievable level of geometric complexity in end user industrial applications in areas such as the aerospace and automotive industries. However these processes currently lack reproducibility and repeatability with some 'prints' having a high rate requiring rework or even scrapping. It is therefore imperative that robust quality systems can be implemented such that the waste level of these processes can be eliminated or decreased. This study presents an artefact that has been optimised for characterisation using computed tomography (CT) with representative AM internal channels and structures. Furthermore the optimisation of the CT acquisition conditions for this artefact is presented in light of analysis of form, internal feature dimensions and position and material porosity.

Keywords: Additive Manufacturing, Porosity Analysis, Traceability, Polymers, Artefact Design

1 Introduction

Additive Manufacturing is used in industrial applications such as aerospace automotive and medical engineering, from prototyping to end user parts. In such applications use of AM allows for high geometrical complexities to be achieved with no additional cost being incurred. Currently AM methods lack true reproducibility, meaning that in some cases large numbers of components have to be scrapped or reworked. Therefore there is a clamour within industry to develop a robust and reliable methodology for non-destructive evaluation of AM produced components.

Industrial Computed Tomography has been traditionally utilized to characterize material and component structures associated with traditional techniques as well as organic and biological structures which can be seen to be akin to the complex network structures produced through AM to save mass.

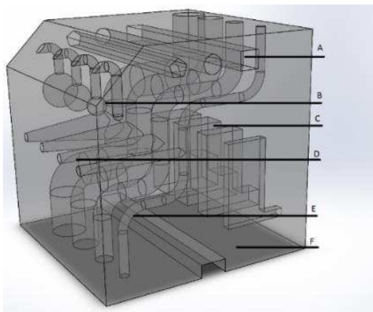
Recently there has been a growing interest internationally to investigate the efficacy and practicality of using CT to both qualitatively and quantitatively analyse AM produced components, however, with both technologies at a relatively early stage a number of challenges exist in trying to achieve this.

- This paper will detail the development of a CT-specific artifact produced using representative industrial AM technologies. This has been developed with a view to encompassing the optimization of the measurement technique such that a reliable and robust comparison of the different AM methods can be accomplished.
- Outline validation of CT method using coordinate measurement is further detailed.

2 Artefact Design of Intent

Benchmarking artefacts for AM are used to test process limitations and optimisation of method, this field has been established by Kruth and Moylan [1] [2]. Currently artifact produced for the use in CT by ISO and VDI/VDE standards such as CT tetrahedron or Calotte Cube. Used for geometrical characterization by measuring surface roughness form and dimension. Artefacts can also be included in traceability and stability reports, allowing end users to track suitability. Conversely current generation artefacts are not optimized for the use in CT, features are design externally, producing lower resolution scan using CT due to the overall size of the artifact. Using recommendations from ISO 10360 and inspiration from Kruth and Moylan an artifact for CT with optimised internal structures has been designed. Printed on representative industrial AM machine for end user parts, a test for suitability and stability has been investigated.

The proposed artifact will allow for multi material AM printing using optimised CT parameter and the following features will be examined:



1. internal structures
   - A. Internal overhangs
   - B. Spheres
   - C. Thin walls
   - D. Drafted exits
   - E. Channels

F. Porosity
2. Optimised CT operational settings

Figure 1: Additive manufactured HUDD cube for Computed Tomography

3 Methodology

3.1 Key variables

During the optimisation phase CT operational settings have been analysed, with a view to determine optimal parameters for each material combination in this study. As there are no accepted test procedures available, vdi/vde 2617-13 and ISO 10360-13 requirements were used as a basis. ISO and VDI/VDE guidelines have not currently been applied widely to direct assessment of internal structures, so this paper details a proof of concept where this has been applied to multiple AM materials and processes. Accuracy of scanning has be determined by evaluation of measurement uncertainties using a design of experiments Taguchi array. Through this determined method the compatibility of geometrical features including form, dimension and porosity have been investigated.

4 Results

The optimisation of the artefact design detailed in this study has allowed for the repeatable and accurate characterisation and analysis of internal features of AM components for form, dimension and porosity. A study of multiple polymers available currently in industrial AM machines have been evaluated for beam attenuation, beam hardening artefacts and noise using the HUDD cube. Operational settings such as filtration, current, voltage, etc. were investigated using the artefact to check for levels of variation in results. This was achieved using Taguchi orthogonal array and measuring signal to noise ratio for each parameter.

Table 1: Artefact CT scan Parameters

X-ray		Filter		Resolution		Projections	
Kv	**µA**	**mm**	Material	**µm**	**Magnification**	**Total**	**Increment**
180	45	0	N/A	79.08	2.53	1583	0.2274

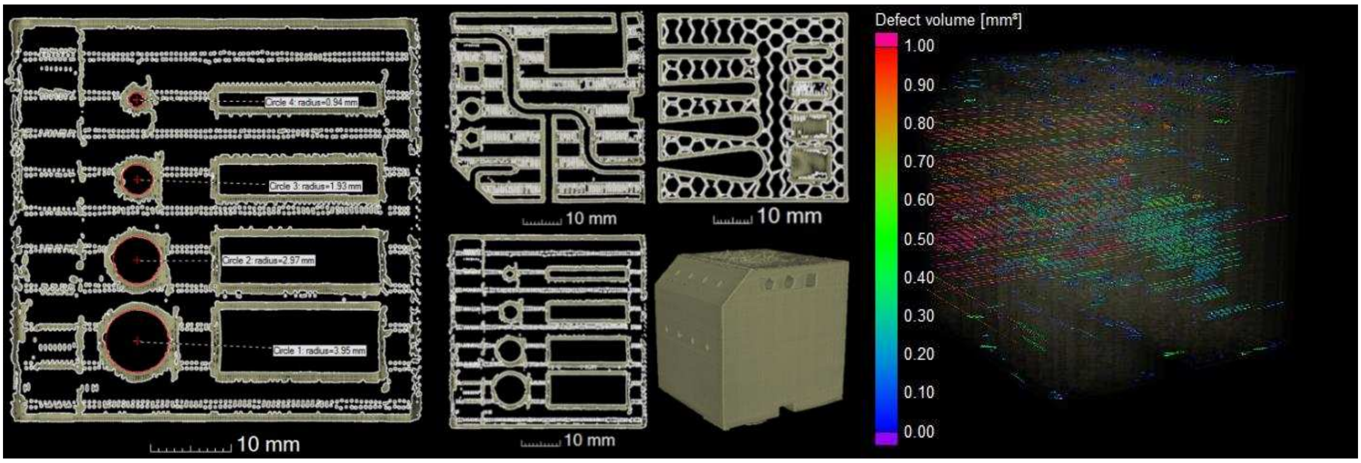


Figure 2: Prototype Fused Deposition Modelling HUDD artifact CT scan

5 Discussion

In this study an AM produced artefact that can be repeatedly characterised by CT has been successfully specified and developed. This paper has concentrated on different polymers available in contemporary industrial AM. Analysing internal features using CT has great significance as intricate cooling systems for injection moulding allowing for faster cooling and quicker ejection and heat exchangers with increased performance are being developed using AM technology.

Future work will entail the further development and application of this artefact more widely to use with metallic AM materials and indeed this work is ongoing.

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