RAPID 3D INSPECTION OF AM COMPONENTS USING CT: FROM DEFECT DETECTION TO THERMAL PERFORMANCE SIMULATION

Material available:

- Paper below
- Short video presentation
- Live presentation at 11:40am in the Synopsys virtual room

Celia A. M. Butler[1,2], David Harman[1], Bethan Nye[3], Borja Lazaro Toralles[3], Nathanael Turner[3], and Nick Brierley[3]

[1]Synopsys NE Ltd; [2]University of Exeter; [3]Manufacturing Technology Centre;

SUMMARY

Metal Additive Manufacturing (AM) can be used to produce topologically complex designs, which are difficult or impossible to engineer using traditional manufacturing techniques. Non-destructive inspection and testing of such structures can be challenging due to internal or inaccessible features. Inability to find and correct for defects in built parts can lead to increased performance testing, potentially more failures and therefore more scrappage of parts, wasting precious time and resources.

Here a "hot box" heat exchanger is presented as an industrial example of how X-ray Computed Tomography (CT) can be used as part of a non-destructive testing process to inspect complex structures.

From the CT scan, an image-based model was built to identify and analyse defects and deviations from the original design. At this stage, the part could be deemed fit for use if any deviations fall within allowed tolerances or inspected further using image-based simulation. Inspection at this stage also means changes can be made to the manufacturing process for future manufacturing runs (such as a design change for trapped powder extraction).

Image-based simulation allows virtual performance testing of the "real" part (as opposed to a CAD idealisation). This includes any defects, pores, warping, etc. which could have occurred during the manufacturing process.

In the "hot box" heat exchanger example, defects in the structure were identified. This was mainly in the form of trapped powder in narrow channels, and some deviation to the lattice structure. An image-based simulation of the "as-built" structure was undertaken to show the impact of these deviations from the "as-designed" structure. This simulation focuses on the thermal performance of key areas of the "hot box".

The ability to perform dimensional, integrity and surface inspection in a single workflow proved to be highly beneficial for the current production process of the "hot box". It has the potential to reduce inspection time and remove the need for additional inspection equipment, therefore reducing costs, cycle times, and potentially increasing workable floorspace.

THE "HOT BOX"

Manufacturers repeatedly ask the following questions: "What are the differences between my design and the part that is actually manufactured via AM, and more importantly, how will these differences affect performance in the real world?" This industrial use case shows how to use CT and image-based simulation to answer these questions.

The "hot box" (shown in Figure 1) is a test jig designed to ascertain performance of a particular structure before a bespoke heat exchanger is designed. It has a lattice structure through which air passes, and cross-corrugated channels for liquid coolant, making this a complex design, impossible to traditionally manufacture and subsequently inspect without cutting the part open.

It was manufactured using AM from AlSi10Mg by HiETA Technologies Ltd., and was CT scanned at the Manufacturing Technology Centre (for details see: Turner et. al. 2019) to visualise and quantify defects, and the output reconstructed to be used to build an image-based model for simulated tests.

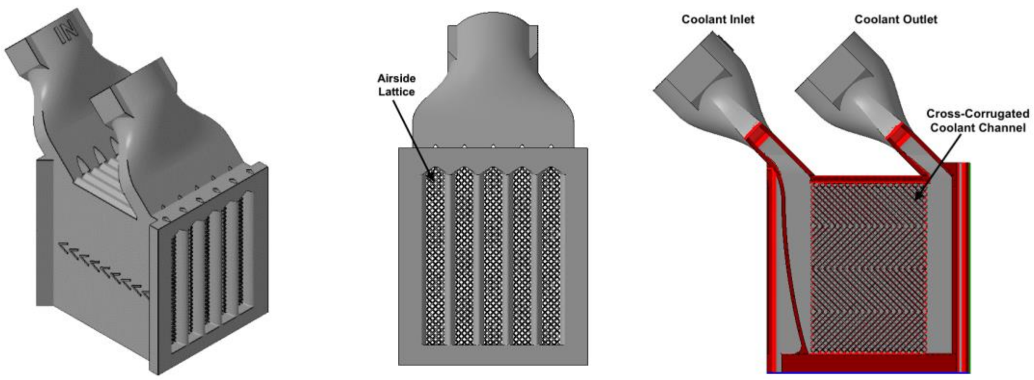

Figure 1: "Hot box" heat exchanger, image courtesy of HiETA Technologies

VISUALISING DEFECTS

Images obtained from the CT scan were reconstructed into a 3D image volume and used to inspect the topology of the structure. The reconstructed image data was imported into Simpleware™ ScanIP (Synopsys, Inc. Mountain View, CA) for image processing and mesh generation. Accurate surfaces were determined using automated segmentation tools, including the local surface correction filter to counter beam hardening effects.

The Simpleware Surface Deviation tool compared the "as-designed" CAD surface to the "as-built" AM surface, and identified 3 areas where they differed. These regions are shown in Figure 2 below - trapped powder (dark blue, both images) and deviation from the designed lattice structure (right image, dark blue and red)

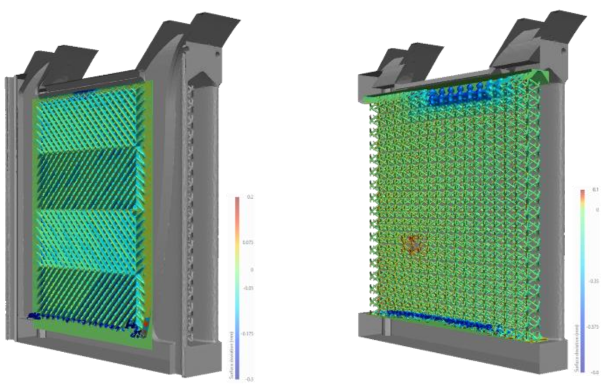

Figure 2: Output from the Surface Deviation Tool (Simpleware ScanIP) between the "as-designed" and "as-built" image-based model.

MESHING FOR SIMULATION

In order to understand the performance of the AM part including its defects, a full volumetric mesh suitable for CFD simulation was generated ("image-based model") using the Simpleware FE Module. This image-based mesh comprised three parts: Metal, Fluid and Air, complete with assigned boundaries for inlets and outlets for fluid flow regions.

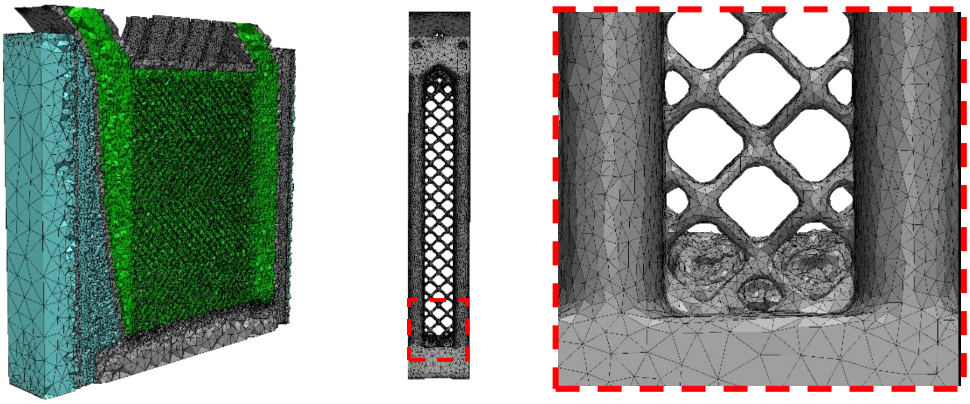

Figure 3: Multipart CFD mesh (generated using Simpleware ScanIP)

THERMAL SIMULATION COMPARISON

Simulation and comparison of thermal behaviour was conducted in COMSOL Multiphysics®, with coupled heat transfer and laminar flow. The temperature distribution in coolant flow through the channels is shown in Figure 4. Deviation from "as-built" geometry is most apparent towards the base of the heat exchanger, and not only is the overall cooling from inlet to outlet greater in the "as-built" geometry, but is visibly less uniform in the vertical axis. This particular scenario shows that the "as-built" part performs worse than the "as-designed" part due to geometrical deviations.

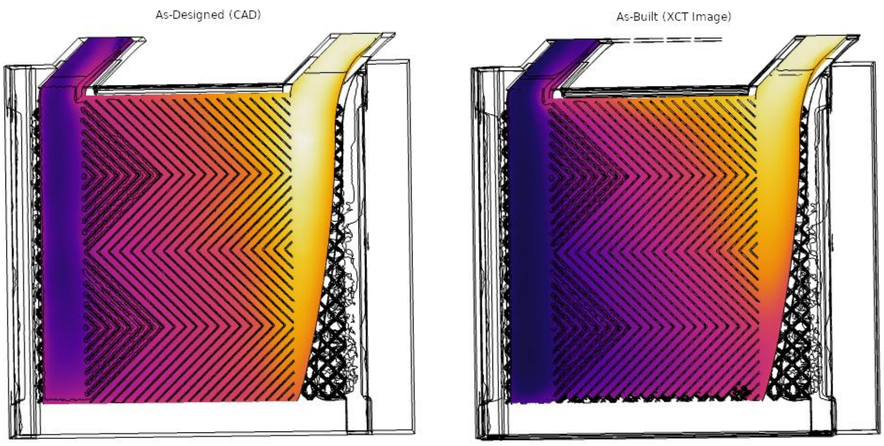

Figure 4: Thermal Simulation showing difference between "as-designed" CAD based simulation and "as-built" image based simulation.

CONCLUSION

This industrial use case shows the importance of X-ray CT and image-based modelling for non-destructive inspection and testing. This workflow allows users to close the design loop and truly understand how any unexpected defects and inconsistencies in the manufactured part can affect real world performance, allowing better allocation of time and physical test resources.

REFERENCES

Turner, N., Brierley, N. and Townsend, A., 2019. 3-in-1 X-ray Computed Tomography. In: 9th Conference on Industrial Computed Tomography (iCT), 13-15 February 2019, Padova, Italy. [Online] NDT net [Accessed 14 April 2019]. Available from: https://www.ndt.net/search/docs.php3?showForm=off&id=23702