Joint Special Interest Group meeting between euspen and ASPE
Dimensional Accuracy and Surface Finish in Additive Manufacturing,
KU Leuven, BE, October 2017
www.euspen.eu

Method for characterizing defects/porosity in additive manufactured components using computer tomography

Ahmed Tawfik[1], Radu Racasan[1], Liam Blunt[1], Paul Bills[1]

[1]*ESPRC Future Metrology Hub, Centre for Precision Technologies, School of Computing and Engineering, University of Huddersfield, Huddersfield HD1 3DH, UK*

E-mail: Ahmed.Tawfik@hud.ac.uk

Abstract

The key barrier for many industries in adopting additive manufacturing technologies is the lack of quality assurance and repeatability. Defect/porosity analysis is the most important inspection step for any additively manufactured components.
This paper presents a method for the detection of defects/porosity in additive manufactured components using computer tomography. A Nikon XTH225 industrial CT was used to analyse the relative size and location of the defects and assess the capability of the inspection process based on different levels of X-ray detector magnification. To reduce the number of process variables, all the measurement process parameters, such as filament current, acceleration voltage and X-ray filtering material and thickness, are kept constant. The acquired data processing, surface determination process and defect analysis was carried out using the VgStudio Max (Volume Graphics, Germany) software package.
One Ti6AL4V component built using an Arcam Q10 electron beam melting machine (EBM) was used. The results obtained from the XCT scan are compared to the physical defect analysis, by sectioning the component and confirming pore size and location using focus variation interferometry. The effect of surface determination, repeatability and results' accuracy are discussed. The main focus of the study is on providing best practice regarding the selection of inspection parameters such as magnification to accurately perform the defect detection.

Porosity, Defects analysis, Additive Manufacturing, Computer tomography

1. Introduction

Additive manufacturing (AM) is relatively new technology, with the absolute ability of producing complex shapes that are impossible to be made using traditional subtractive machining.
At the moment there are several challenges stopping most manufacturers using additive manufacturing techniques in producing critical components. These include a lack of repeatability, absence of well-established quality control system and in-consistent mechanical properties due to internal defects/porosity and the lack of well operating monitoring process that can detect imperfections (ex: in-complete fusion or porosity), some of which have been highlighted previously by the UK AM special interest group (SIG) (Everton, Hirsch, Stravroulakis, Leach, & Clare, 2016)
Most manufacturers are not yet prepared to rely on additive manufacturing due to the uncertainty about meeting design intent and the overall integrity of the component. The existence of internal pores/defects cannot be avoided, furthermore the effect of any pore on the mechanical properties and fatigue life of the component is not well studied. At the moment 100% inspection is required, this inspection is adding costs and time to the already very expensive additive manufacturing process.

2. Methodology

This experiment is investigating the effect of magnification on defect measurement accuracy, using a Nikon XTH225 industrial CT. The sample was scanned with different levels of magnification but all the other settings were optimised for the material and kept constant. The magnifications used were 2.5, 5, 10 and 15 for each scan, the position of the largest pore within the measurement volume was used as a marker to determine that the same volume was assessed in each measurement.

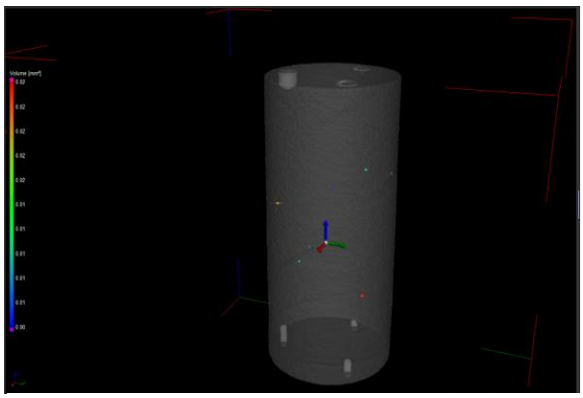

Figure 1 3D view of the pores detected with Mag 2.5

3. Results

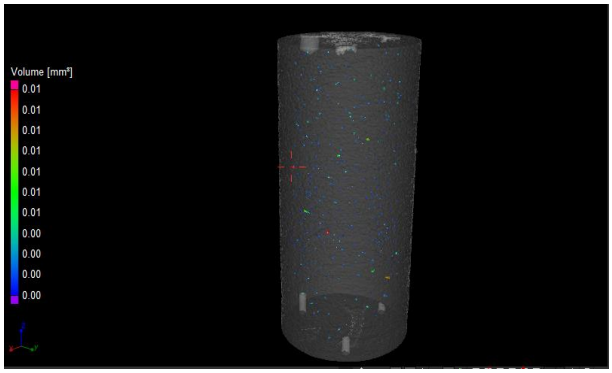

Figure 2 3D view of the pores with Mag. 5

The analysis of the data taken at 2.5 magnification suggest a defect volume ratio of zero (see figure 1). This increases to 0.03% at magnification 5 (see figure 2) and further increases with the level of magnification. Overall the results of the study show that defect volume ratio is inversely proportional to voxel size (see figure 3).

This means that to detect small pores the voxel size should be smaller 20 µm. From the graph it was noted that when the voxel size was reduced from 20 µm to 13 µm the percentage of the defect volume ratio significantly increased. The problem with using a small voxel size, and therefore high magnification, is that most industrial components will not fit within a single scanning volume and therefore time taken for scanning and data analysis will be significant and in many cases not feasible. This is a potential barrier to industrial use of the technology for in-line part inspection.

Table 1 Defect volume % VS Voxel size mm

Defect volume %	Voxel size (mm)	Magnification
0	0.079	2.5
0.03	0.03991	5
0.79	0.02	10
1.78	0.01336	15

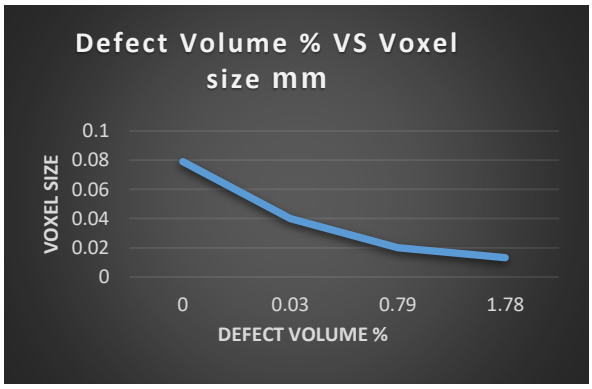

Figure 3 Defect volume% VS Voxel size µm

5. Discussions

Using 3D Tomography to evaluate the density of the part is very promising, but obtaining the accurate geometry of a pore can be difficult and would require verification especially if the pore is not spherical as discussed by Jones et al. (Jones, Atwood, Poologasundarampillai, Yue & Lee, 2008). At high magnification detecting small pores is very challenging due to the need to threshold data to remove noise, this issue was partly investigated by Koseki et al. (KOSEKI, HASHIMOTO, SATO, KIMURA & INOU, 2008). For this experiment all the pores less than 20 µm in diameter were filtered and assumed to be noise. In the next stage of this study this assumption will be verified by sectioning the sample. The sample will be machined in stages and measured using focus variation, by machining 20 µm each stage.

This experiment shows that by increasing the magnification the number of detected pores is increasing; the big pores detection accuracy also improves. This was discussed by KIM el al (Kim et al., 2014) stating that 7.5µm Voxel size is sufficient to detect porosity accurately. With the Nikon XTH225 industrial CT 7.5µm the magnification will be 20, so the sample must be less than 8mm diameter. The detected diameter of the two largest pores (around 0.6 mm) within the measurement volume was reduced by 9.8% from magnification 10 to magnification 15.

Whilst scanning at high magnification undoubtedly improves the accuracy of the obtained results there are significant practical limitations in doing this. In an industrial environment it is not practical to use scanning strategies that have high acquisition times or are limited to small sample volumes. In non-safety critical and partially optimised components small volume pores may be largely insignificant to the performance of the component. However, given the ubiquity and inherent potential of AM as a technology the optimisation of design intent will dictate that this may not always be the case.

References

[1] Everton, S. K., Hirsch, M., Stravroulakis, P., Leach, R. K., & Clare, A. T. (2016). Review of in-situ process monitoring and in-situ metrology for metal additive manufacturing. Materials & Design, 95, 431-445

[2] Jones, J., Atwood, R., Poologasundarampillai, G., Yue, S., & Lee, P. (2008). Quantifying the 3D macrostructure of tissue scaffolds. *Journal Of Materials Science: Materials In Medicine*, *20*(2), 463-471. http://dx.doi.org/10.1007/s10856-008-3597-9

[3] KOSEKI, M., HASHIMOTO, S., SATO, S., KIMURA, H., & INOU, N. (2008). CT Image Reconstruction Algorithm to Reduce Metal Artifact. *Journal Of Solid Mechanics And Materials Engineering*, *2*(3), 374-383. http://dx.doi.org/10.1299/jmmp.2.374

[4] Kim, T., Yue, S., Zhang, Z., Jones, E., Jones, J., & Lee, P. (2014). Additive manufactured porous titanium structures: Through-process quantification of pore and strut networks. Journal Of Materials Processing Technology, 214(11), 2706-2715. http://dx.doi.org/10.1016/j.jmatprotec.2014.05.006