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INSPECTION OF ADDITATIVE MANUFACTURED SAMPLES WITH COMPUTED TOMOGRAPHY

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ABSTRACT

Additive manufacturing enables 3D printing of complex shaped parts. Due to the shaped geometries, the accessibility, and the surface quality the inspection with classical NDT methods reaches limitations. Because of the welding process inner defects like pores, cracks, unconsolidated powder may occur and need to be detected above a certain threshold. Computed Tomography is a potential method to provide information of inner structure characteristics. The question is how suitable is Computed Tomography. This paper will discuss these topics at artificial defects.

Keywords: additive manufacturing, defects, porosity, computed tomography

NOMENCLATURE

1. INTRODUCTION

Additive manufacturing enables 3D printing of complex shaped parts. Due to the shaped geometry, the accessibility, and the surface quality the inspection with classical NDT methods reaches limitations. Because of the welding process inner defects like pores, cracks, unconsolidated powder may occur and need to be detected above a certain threshold. Computed Tomography is a potential method to provide information of inner structure characteristics. Therefore, three studies were performed answering this question reaching from small lab samples to complex components and reference samples. This will be discussed at some lab applications.

2. METHODS

The studies were performed at two CT systems at the TESTIA lab, Munich. The first CT machine is designed for small samples and lab test samples (Figure 1). It was recently updated to fulfill the new requirements for AM applications. The second one is used for inspection and service applications with a 300 kV x-ray source (Figure 2).

X-Ray Source	Viscom 225; 160
Detector	VAREX XRD 3025, 3000x2500; 100 µm
Max. voltage	225 kV
Max. power	225 W
Max. resolution	~ 3 µm
Max. sample size (voxel size 66 µm)	Small and medium sized samples Ø 66 mm, h 60 mm Ø 120 mm, h 60 mm (with range extension)

FIGURE 1: Lab system; recently upgraded

X-Ray Source	X-RAY WorX XWT-300-CT
Detector	Varian 4343
Max. voltage	300 kV
Max. power	350 W
Max. resolution	~ 3 µm
Max. sample size	Small, medium and large sized components Ø 500 mm, h 1000 mm (with range extension)

FIGURE 2: CT machine for inspection and service applications

Using both machines offers to possibility to inspect a wide range of samples from small lab ones to large components from serial production. Since both have similar control and testing features a comparison is feasible.

3. RESULTS AND DISCUSSION

One study was performed at test samples with and without artificial defects like pores, inclusions, or remaining powder. This was done mainly at cylindrical specimen to focus first on the internal features.

The aim of a second study was to evaluate the potential of this NDT method for small and large complex components. Therefore, components with variations in shape, surface roughness, size, inner and outer surfaces, and difficult to access areas were of interest.

The third step was looking into different potential reference samples to check the reliability of CT for inspection of AM applications.

An example for evaluation of artificial porosity is shown in Figure 3. The small samples contain a high degree of porosity which can be seen on 2D cuts as well as in 3D.

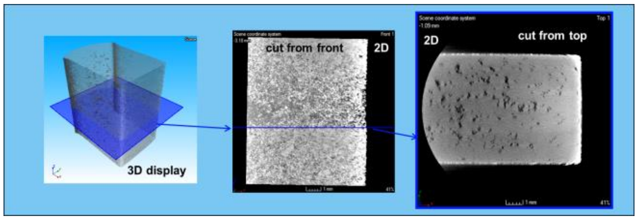

FIGURE 3: display of artificial porosity

In addition commercially available tools for supported porosity evaluation were tested. It was possible to highlight the porosity color-coded and obtain some statistical data like position, size, volume, and distribution (Figure 4).

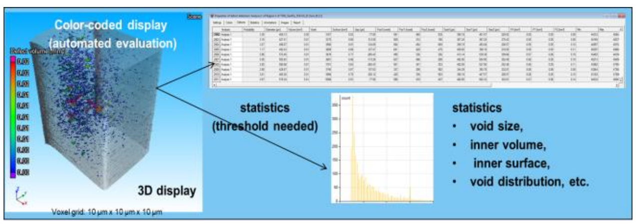

FIGURE 4: supported porosity evaluation with commercially available tools

The tools are offering an overview of inner structure characteristics.

The study was continued with cylindrical samples with drilled holes for evaluation of well-defined artificial defects. The diameters range from 0.3 mm to 1 mm with a fixed depth of 2 mm and were randomly chosen (Figure 5 and Figure 6).

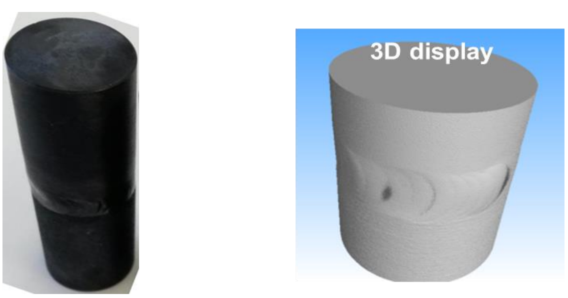

FIGURE 5: cylinder with inside bore holes; left: image; right: 3D CT image

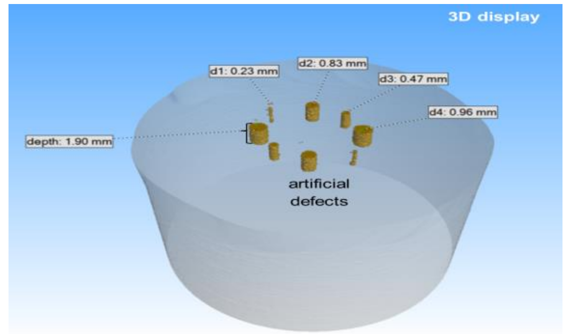

FIGURE 6: 3D display of CT volume with drilled holes

The drilled holes with varying diameters were clearly visible on the CT images with a voxel grid size of 25 µm. This size is far below the "detection limit" of 3 x the voxel size. An example is shown in Figure 7.

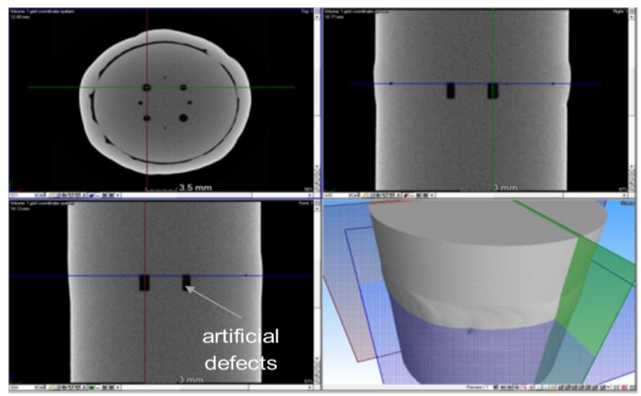

FIGURE 7: supported porosity evaluation with commercially available tools

Besides drilled holes also foreign particles with higher density became detectable with the chosen testing and sample parameters.

During the second step of the investigation more complex shaped components were chosen not only for defect characterization but also to take advantage of 3D volume for geometrical property evaluation. This leads to an additional benefit of CT inspection, the option of nominal-actual comparison (Figure 8).

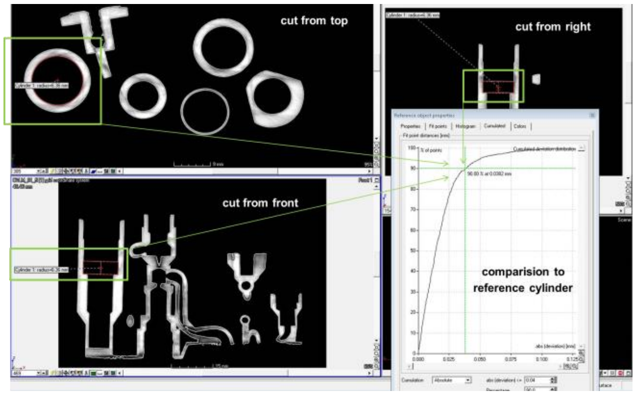

FIGURE 8: Evaluation of dimensional properties

Part of this study was also the collection of ideas for a potential reference sample that could be measured with regular CT-testing to monitor changes and the ability to detect potential defects of certain sizes. One possible suggestion could be a cube with varying well defined inner structure characteristics (Figure 9).

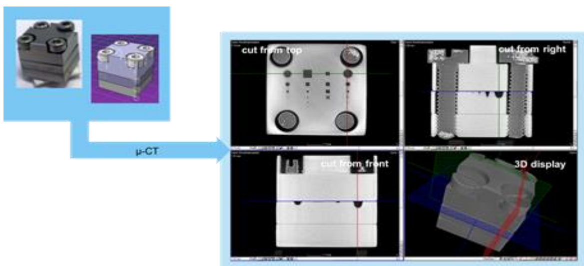

FIGURE 9: Potential example of a reference cube

4. CONCLUSION

The studies presented in the abstract are giving an idea of the ability of CT for testing of additive manufactured parts. It has the potential advantage of contact-less testing of complex shaped parts. But the reliability as well as artefacts caused by changes of wall thickness and other disturbances have to be considered. Therefore, a standardized approach is needed to monitor the system as well as for the testing procedure.

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