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Utilising Computed Tomography as NDT Technique in Additive Manufacturing

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Abstract
Additive Manufacturing (AM) is presently revolutionising industrial production in many sectors (Aerospace, Automotive, PowerGen, Oil&Gas, Medical, etc.) and is expected to substantially substitute traditional molding and casting processes within the next decade to come. For many workpieces made of plastic and metal based materials, AM tends to be the more convenient manufacturing technique due to their complexity and geometry.

Keywords: Additive Manufacturing, AM, Computed Tomography, CT, 3D Visualization, Metrology, Standardisation ISO/ASTM.

1. Introduction

Apart from other known non-destructive techniques to assure quality of AM products, computed tomography (CT) turns out to be one of the most efficient NDT methods. Not only does CT enable the three-dimensional volumetric visualization of indications and internal geometries that traditional NDT methods can scarcely or not access, it also allows to be used for metrology application tasks, such as dimensional measurement of features, variance analyses (CAD data to part, part to part).

2. Content

In view of new types of defects and flaws to be detected in AM parts, CT can meet requirements for increased resolution, higher penetrability and X-ray scatter-corrected volume data sets of workpieces printed of various plastic or metal materials, even if they are manufactured from dense materials (e.g. Ti6Al4V, Inconel 625/718, CoCr, etc.) allowing for reliable and reproducible measurement results.

When irradiated, dense materials tend to produce physical X-ray backscatter, in particular for cone beam CT (i.e. using flat panel detectors) that is used to achieve fast CT scan times. This backscatter is negatively influencing the CT image and volume quality, as displayed by the example of a high-pressure turbine blade [1].

The proprietary «scatter|correct» method allows to measure the backscatter and deduct it from the CT volume data set to achieve a nearly scatter-free CT volume enabling to do analysis such as wall thickness measurements, as shown in the HPT blade example [2].

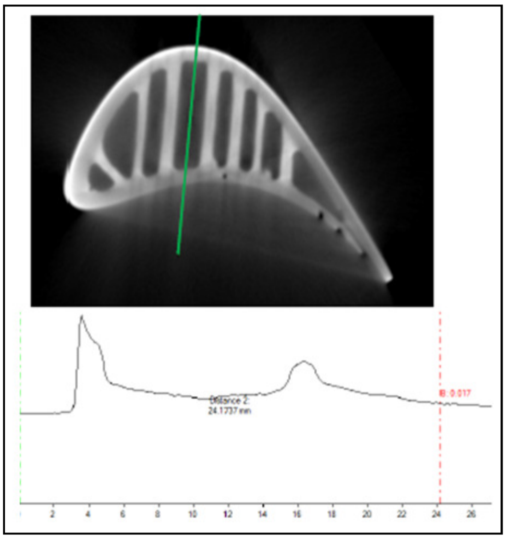

Figure 1. HPT blade CT image slice with physical backscatter [1]

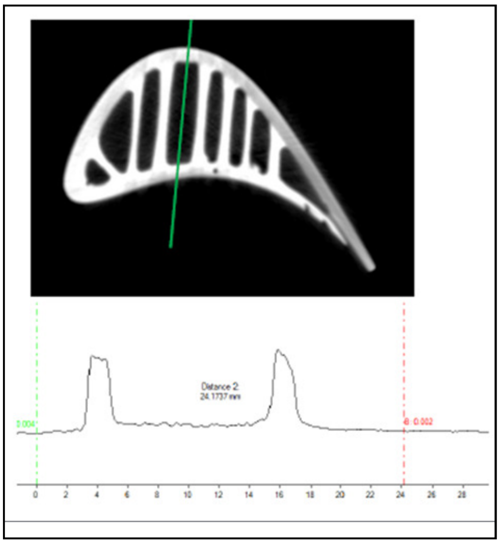

Figure 2. HPT blade CT image slice without physical backscatter [2]

Achieving a high level of CT resolution is essential when AM parts are inspected, defects such as powder entrapments, porosities and cracts are usually smaller than in traditionally casted parts. Cone beam CT allows for both, full part scanning and region of interest (ROI) part scanning, dependent on which level of resolution is required to detect the expected defects [3]

Computed tomography can complement dimensional analyses of coordinate measurement machines since it allows for measuring both, internal and external features at high precision and reproducibility.

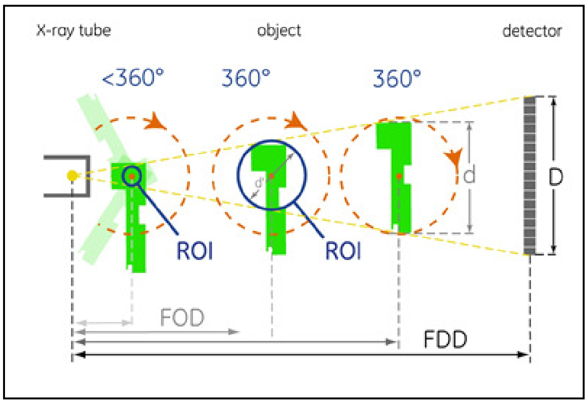

Figure 3. CT principles – full and ROI scan [3]

Some examples demonstrating the functionality range that CT can provide both, in failure analysis and in dimensional measuring are shown here below [4], [5].

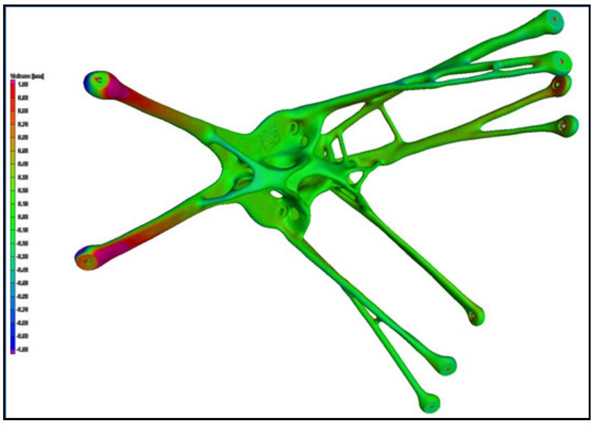

Figure 4. CT example reaction wheel bracket[1], CAD analysis [4]

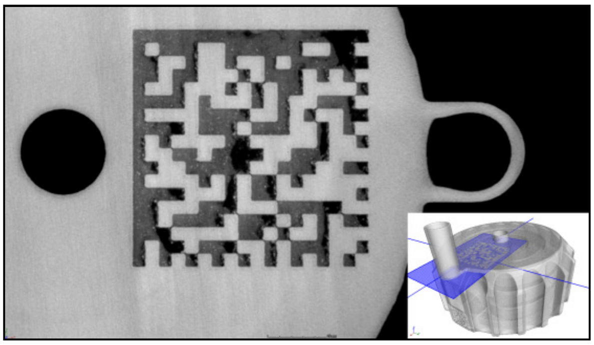

Figure 5. CT example rotary carousel, powder entrapments [5]

In addition to NDT tasks that concern the entirely printed workpiece, high-resolution CT allows for incoming inspection of the essential raw material required for 3D printing – the powder. Granulometry, particle size distribution and sphericity of AM metal powders (newly manufactured and recycled compounds) can be inspected [6], [7].

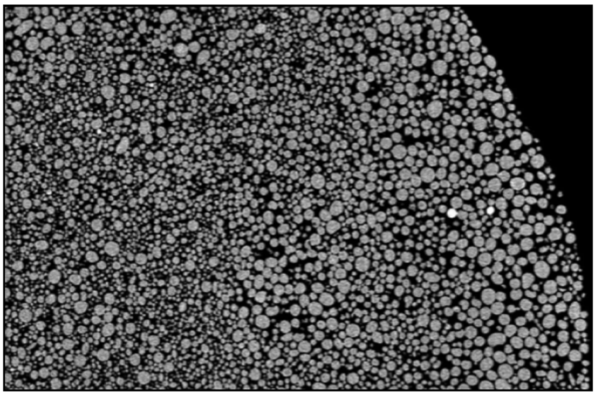

Figure 6. CT example powder – structural analysis [6]

Even material homogeneity inside the powder grains may be analysed by CT, subject to sufficient resolution and contrast.

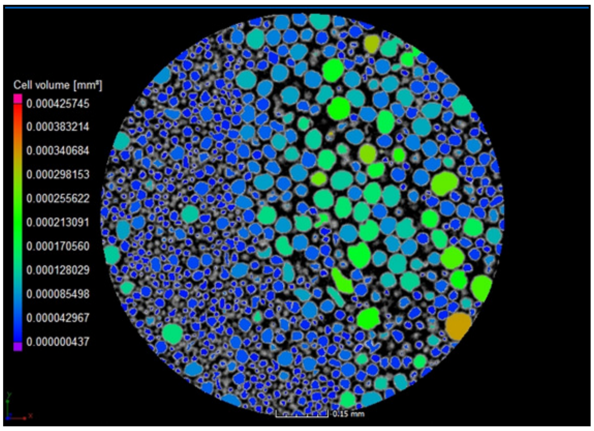

Figure 7. CT example powder – particle size analysis [7]

Being complementary to other NDT techniques such as in-situ monitoring during the AM process or on or near surface based eddy current or ultrasonic inspection, CT can help setting guidelines for volumetric quality assurance of AM parts[2]. Hence, standardisation organisations such as ISO (ref. TC 261) and ASTM (ref. F 42) rely on the recommendations and the expertise of CT system suppliers and CT users among the AM community members.

Thanks to improved automatic workflows, CT continues its move from being a traditional expert R&D device towards the use as an automatic measurement technique on or close to the production floor. Further automation steps such as the use of robot based manipulation units for unmanned part handling coupled with assisted defect recognition (ADR) have been developed and will find their way into the shop floors [8, 9].

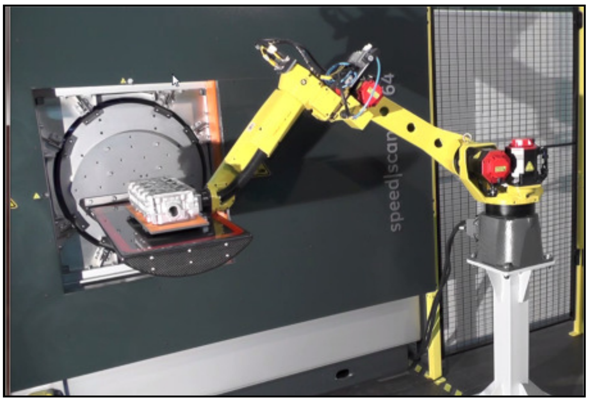

Figure 8. CT solution “speed|scan” with robotic part handling [8]

Figure 9. CT solution “v|tome|x m 300” with robotic part handling [9]

3. Conclusion

Computed Tomography is a leading technique for non-destructive testing of additively manufactured parts and complementary to other NDT techniques already in use. It fits the AM industry’s needs for quality assurance today and in future, if it delivers enough X-ray energy, resolution, contrast and speed.

Key enablers for future AM production based control by CT are a high degree of automation as well as an efficient-communication between the different manufacturing and quality checks within the AM supply chain.

References

[1] Reiher T., Koch R., "FE-optimization and design of additive manufactured structural metallic parts for telecommunication satellites", Paris Space Week, Paris, Feb. 2015.

[2] Herderick E.D., “Additive manufacturing applications and development: the past, the present and an exciting future”, IQPC Additive Manufacturing Conference, London, Feb. 2017.