X-RAY AND COMPUTED TOMOGRAPHY AS A TOOL FOR QUALITY ASSURANCE, PROCESS OPTIMIZATION AND METROLOGY INSPECTIONS IN THE FIELD OF ADDITIVE MANUFACTURING

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Abstract:
At the moment computed tomography is the only available technology to give an insight on quality, geometrical features and process quality of highly complex additive manufactured parts. With different application examples I will show the challenges for the quality of AM parts and influences by design and production process.

Keywords: Radiographic testing (RT), Computed Tomography (CT), Metrology, Process Optimization, Additive Manufacturing (AM)

1. INTRODUCTION
Computed tomography (CT) goes light years beyond regular 2-D X-ray technology to deliver accurate three-dimensional images of scanned objects, including their voids and areas of differing density. It has become one of the most important and powerful non-destructive testing (NDT) methods - an achievement resulting from the continuous improvement of CT scanning and reconstruction methods.

Today, CT is used for research and development, failure analysis, process and quality control, small series inspection, combined DR-CT inspection, defect and material analysis, assembly checks and, becoming more and more important, metrology, i.e. dimensional measurements.

2. EXPERIMENTAL METHOD
The experiments were performed either with a standard laboratory dual-source micro-CT or with a customized high-power industrial CT. Depending on the material, geometry and wall thickness of the additive manufactured (AM) part we chose the most suitable solution to achieve the best results.
Figure 1: Different x-ray and CT solutions for different applications: Cheetah EVO, FF20 and FF85.

3. CHALLENGES FOR ADDITIVE MANUFACTURING

Different application examples from different industries will be presented during the presentation to show challenges, problems and typical defects for this production method.

Due to the free part complexity in the AM production process the parts can have a complex outer shape and a lot of internal features like lattice structures or a complex network of channels. This complexity leads to increased demands for the inspection of such parts. In a lot of traditional manufactured parts the 2D x-ray inspection already gives a sufficient level of information about the part and the associated production process steps. For the majority of AM parts the inspection by Computed tomography is the only method that delivers a sufficient level of information.

Figure 2: Flow measurement nozzle with internal defects.

Figure 3: Air probe with internal defects (closed channels).
Industrial X-ray and CT are powerful inspection methods for the final part. In this more traditional way you can assure the final quality of a part. With the high depth of information delivered by CT this method can also be used to give a deeper understand of the production process and single process steps.

This reaches from the CT analysis of powder which is the raw material in the powder bed fusion AM printing process to the inspection of test cubes used for the parameter development.

With the inspection of a small portion of raw powder the CT analysis can deliver information on the powder particle volume, porosity and sphericity. This information delivers insight into the condition of the powder and the powder production and recycling process.

Another very interesting application is the CT inspection of test cubes for the parameter development. At the moment the users have to make a lot of effort in developing the right printing parameters and materials for their products. For this development the user is printing hundreds of test cubes with variances in printing parameters to find the optimum parameter setting. In the following analysis this cubes are often inspected with standard metallographic analyses like microscopic analysis of micro sections or density measurements. These analyses can be done much faster with the CT scanning of such test cubes. This procedure is not only much faster but also gives more information from every single cube over the complete volume not only the single micro section.
4. **CT METROLOGY**

With the right system configuration CT is a technology to do highly precise and repeatable measurements for geometrical features. Especially for additive manufactured parts with their complex internal features like cooling channels, bionic and lattice structures it is crucial to measure internally.

In this example a bionic optimized helicopter bell crank with a lot of free form surfaces is shown is shown with different types of measurements.

![Figure 7: CT metrology for an optimized 3d printed helicopter bell crank.](image)

5. **CT AS A TOOL FOR PROCESS OPTIMIZATION**

During the presentation different examples how to use an industrial CT scanner as a tool for process optimization for the additive manufacturing production process will be shown. With all the previously mentioned analyses reaching from the raw powder over the process parameter test cubes and the inspection of the final part the industrial x-ray and CT is a powerful tool to get more insights into the additive manufacturing production process and gives opportunities to improve this process regarding quality and production time.
6. RESULTS

With the presentation of these applications from additive manufacturing and the x-ray and CT inspection it was demonstrated how the performance of a today’s x-ray and CT devices, can support the analysis and inspection tasks for quality assurance, metrology and process optimization for additive manufactured samples through different process steps.