# Quality assurance for the complete process chain of Additive Manufacturing with modern metrology techniques

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**Abstract**

In this paper, different approaches for the quality assurance of parts produced with Additive Manufacturing (AM) will be presented. AM is a new way to produce parts in small lot sizes up to a lot size of one. Furthermore these products can easily be constructed with high complexity in a 3D-CAD software system and stored accordingly [1]. Another significant advantage is the low weight of the entire component and its robustness in industrial use. However, the Selective Laser Sintering (SLS) process used for AM does have some associated problems. The most serious one is the inability to secure an accurate prediction in the quality of results, which is ultimately the quality of the components. This is essential for industrial deployment and enforcement in the market.

The possibilities of modern 3D data evaluation for metrology and quality assurance will be presented in this paper for the special application of the plastic SLS process. We use the advantages of different measurement techniques at all stages of a production process for an increased quality of the resulting products. The content of the presented work is the optimization of plastic laser sintering components with regards to their quality requirements to ensure the functionality of their practical use in production, which can be guaranteed and quantified.

To ensure a high quality production different measurement techniques can be used along the process chain. During the production different sensors can be used, such as 2D and 3D imaging sensors. Using these, errors in the production can be detected and classified. If the sensors are used in addition to one another, the likelihood to detect errors increases. Moreover these sensors can be used to speed up the ramp up when

different raw materials are used. The industrial Computer Tomography (CT) can be used to study and capture the necessary quality criteria or aspects in the complete product development process [2]. Then the acquired 3D data is evaluated and adequate 3D solutions are identified to guarantee optimal quality evaluation as well as conclusions for future SLS development and production.

Our presentation focuses on the study and evaluation of 3D data and the conclusions for relevant quality criteria. Additionally, the evaluation results for quality prediction, comparison and for correction are described in order to show how an adequate process control can be achieved with the help of modern 3D metrology techniques.

## 1. Adaptive quality assurance of the product development process of AM with modern 3D data evaluation methods

A variety of parameters, environmental conditions and physical effects during the AM production process have an impact on the product. Similar products can have greatly differing qualities caused by different influences. The lack of geometric accuracy of the parts, depending on the raw material conditioning, temperature control, laser offset cooling, false cooling process, temperature or position in the machine, is a well-known problem.

Due to the possibility of the complete material inspection and the complete geometry acquisition with all internal and external structures, modern 3D techniques offer solutions for the AM problems in the different phases of a product development process. First of all CT and focus variation are used to capture and to study all the necessary quality criteria or aspects in the complete product development process. They are identified and recorded. A distinction is made in component-related features, e.g. geometries, component distortion, material-related features, e.g. resulting porosity, mixing of materials and process-related criteria, for example laser speed, cooling time, location in space. Here the different 3D data types are evaluated. For some criteria the volume information is necessary, like the detection of inner defects, and for some the surface data has to be generated, see for example [3], or scanned, e.g. for geometrical or textural inspections. Therefore different methods have to be developed. This includes also methods for the detection of systematic shape deviations from the expected geometry which is evaluated by nominal-actual comparison based on the 3D data [4]. An example is shown in figure 1.

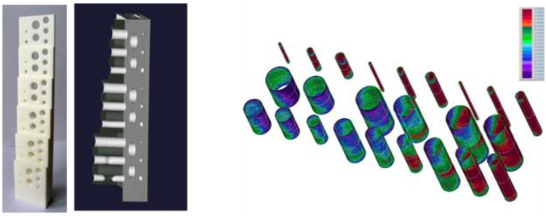

Figure 1: Test part for systematic geometrical error for inner cylinders (left), a cut through the STL-model (middle) and the calculates distances from ideal cylindrical forms (right)

The aim is to determine the product development process with the help of the relevant quality assurance criteria by using non-destructive modern 3D metrology. The end product should have desired and expected properties. This means that after the design and CAD design of a component, the required quality and production criteria are defined. Accordingly, these requirements are used on the one hand to modify the 3D data directly and on the other hand to pre-adjust and fix the various process parameters so that an optimized production of the product is possible and consequently a predictable quality can be achieved.

## 2. Inline Quality Control System for a reliable AM – layer by layer inspection

Using 2D image processing (IP) algorithms and a 2D nominal-actual comparison between the CAD-layer and the actual layer data acquired with 2D sensors, relevant defects like cracks, distortions, layer geometry deviations can be identified inline, during the production process. In the future the user will be automatically informed that an error occured within a layer so that the printing process can be stopped, saving in this way material powder and time, in a word saving costs.

On the other side, at the end of the production process a 3D nominal-actual comparison will take place between the real object, reconstructed from the acquired 2D images of each layer, and the CAD model. Details concerning the geometrical accuarcy and the object surface will be reported.

 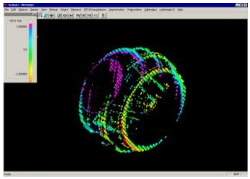

Figure 2: 2D nominal-actual comparison for a layer of a product (left), 3D nominal-actual comparison after the production process (right)

## 3. Sumary and future work

In summary it can be stated that modern 2D and 3D data processing and evaluation methods due to their versatility and benefits are particularly suitable for the various problems that occur during/within a product development process at all stages of the plastic SLS. As further work, for the 3D data evaluation methods, tests are planned for the detailed validation of the statements, such as the correction of systematic geometries errors. We also plan to adapt new 3D software solutions for surface generation for the special application of AM [2]. Considering the Inline Quality Control System an IR sensor is planned to be integrated in order to detect defects like powder layer thickness. In addition an inline parameter correction (e.g. for the laser beam) will be taken in consideration. The automatic calibration of the 3D printers for different powders is also planned to be realised with the inline IP system.

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