Improving the QA of 3D-printed parts

Liz Nickels

Quality assurance (QA) is the new watchword in additive manufacturing (AM). How can manufacturers improve the quality of powder metal parts made using this relatively new, unregulated technology? Liz Nickels spoke to Joseph Weilhammer, Product Manager Metal, EOS Krailling, from EOS GmbH, who considers QA to the vital next step in the development of AM.

EOS, one of the earliest providers of additive manufacturing (AM) technology, was established in 1989 by Dr. Hans J. Langer. It soon became the leading player in high-end rapid prototyping (RP) technology. The company launched its first STEREOS 400 stereolithography system in 1991, while in 1994 it extended its product portfolio to laser sintering, becoming the world's first provider of both stereolithography and laser-sintering systems. A year later the EOSINT M 250 was launched, offering metal 3D printing, particularly for manufacturing metal tools for plastics injection molding.

In 1997, EOS took over the global patent rights for laser-sintering technology and now focuses exclusively on powder-based additive, layer-by-layer manufacturing processes, launching direct metal laser sintering (DMLS^{TM}) in 2004. In 2013, EOS added to its metal material offerings with a new metal material for industrial 3D printing: EOS NickelAlloy HX. Now in 2016, the company has decidedly moved away from its previous rapid-prototyping dominated portfolio to more serial manufacturing applications. With the current emphasis on industrial 3D printing solutions, quality assurance (QA) has thus become a focal point. EOSTATE MeltPool, a QA tool that can monitor the progress of multiple direct metal laser sintering (DMLS^{TM}) products across multiple interlinked laser sintering systems, provides an overview of production-related data. Status, control and reporting software can be used to monitor production on several interlinked systems at the same time. EOSTATE MeltPool evaluates data saved on the systems, prepares it in a clear format and provides an overview of all production-related information at all times.

The tool is modular in structure and can be adapted to the different requirements of users and end customers. For example, it can be extended beyond QA to also cover controlling and machine park management (MPM).

The process software of a laser-sintering system continuously logs important process data in a database on the system's computer. A data-base management system (DBMS) that runs on every system's computer manages this data. EOSTATE MeltPool establishes a network connection to the DBMS and thus enables direct access to all data that logs the process software in the database.

EOSTATE MeltPool filters this data according to the given criteria, manages, saves and exports machine data, creates statistics and enables extensive reporting. The software also allows a system to be monitored by webcam.

The EOSTATE MeltPool system moves the quality assurance process that would otherwise take place downstream into the additive build process. This allows real-time process monitoring and can improve risk management while lowering the costs associated with QA and reducing the time required for this purpose.

EOSTATE MeltPool makes it possible to track components and the automatic monitoring and analysis of the melt pool during the DMLS process – per spot, per layer, per part. The tool, which was developed jointly with plasmo Industrietechnik, a provider of automated quality inspection systems, is suitable for R&D and manufacturing clients with demanding quality requirements.

During the DMLS build process, EOSTATE MeltPool observes the light emitted by the melt pool, and uses hardware that helps to separate the process light from the reflected laser light. The data that is obtained is processed in the software, which offers automatic error correction of the data that is created, as well as process visualization and evaluation in real time. For the purpose of data analysis, the EOSTATE MeltPool analysis toolbox illustrates data in 2D or 3D mappings and enables the evaluation of indication

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FIG. 1
EOS' M 290 additive manufacturing system including the company's EOSTATE MeltPool QA software.

clusters. The tool works based on three advanced algorithms to obtain different data interpretations.

The data that is collected can be used to draw conclusions regarding the quality of the final components. The corresponding parameters (MPM parameters) can be selected using the analysis toolbox, and discrepancies can be automatically noted during the live monitoring process.

EOSTATE MeltPool is available as an extension to the EOS M 290 DMLS system (Figs. 1 and 2).

EOSTATE uses real-time monitoring for EOS systems, recording machine park status and access to current sensor values and pictures.

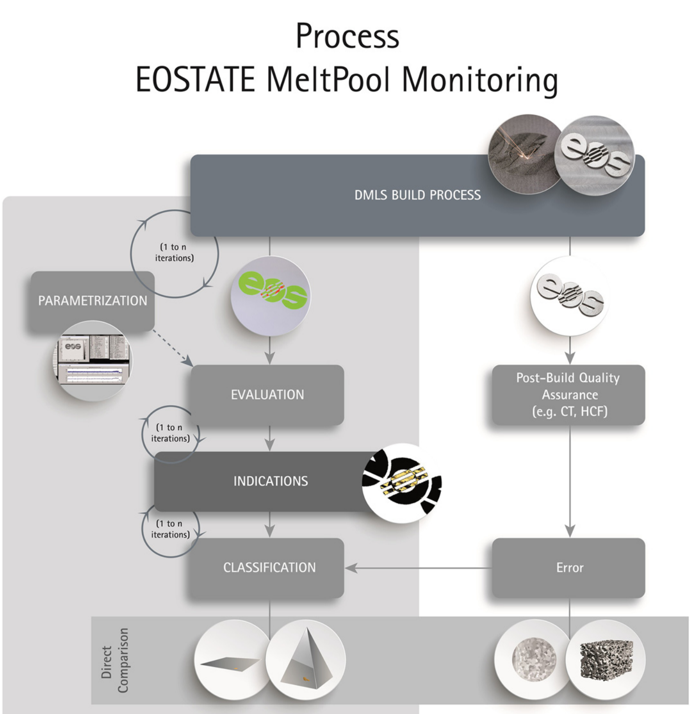

FIG. 2
Schematic of the EOSTATE MeltPool process.

Holistic approach

According to EOS a 'holistic approach to quality assurance' is required to produce successful 3D-printed parts – due to the many new applications for the technology.

'Consistent and repeatable part quality is essential for series production applications,' said Dr. Tobias Abeln, EOS chief technical officer (CTO). 'With its quality assurance concept, which is unique to the industry, EOS covers the three technological elements of additive manufacturing that have a direct influence on the quality of an additively manufactured component – namely, system, material and process. Thanks to the joint development and mutual adjustment of our systems, materials and processes, EOS has established conditions for the best possible part properties.'

'Part quality of an additively manufactured part is always determined by these three key factors,'' Weilhammer told *Metal Powder Report*. 'In order to achieve highest part quality, it needs a good understanding of all three factors and their effects on each other. Whenever one of these factors is being changed, this also has an immediate impact on part quality. So to achieve best part quality these three factors have to be optimally aligned.'

At the company's global headquarters in Krailling, Germany, EOS has reserved an area of around 2300 m^2 for 70 additive-manufacturing systems used for research and development, quality assurance, application and training for both polymer and metal products. At the EOS Oy plant in Finland, an additional 15 systems are being used for the development, qualification and quality assurance of metal materials, while an additional 20 systems are available in the international EOS technology centers in the US, Singapore and China.

According to the company, EOS has been certified to ISO 9001:2008 (''for the development and manufacturing, sales and service of systems and solutions for Additive Manufacturing using laser sintering technology since 1998'') and has put a number of QA measures in place to help ensure that manufacturing standards are reliably observed during production on EOS metal systems. These are tested and validated within the context of the EOS system acceptance test, during which defined reference parts are manufactured and then examined for numerous decisive criteria such as mechanical properties, tensile strength, elongation at break, surface quality and component density. Current DIN and ISO standards are applied for these tests.

Material standards

The materials used in EOS systems have a major influence on the quality of the manufactured component, according to the company. EOS's operations in Finland deals with the development, qualification and quality assurance of metal materials and has been certified to ISO 9001:2008 since 2013 and to the Medical Products Law ISO 13485:2003 since 2012. EOS is also registered for medical material in Europe for class II dental applications under ISO 13485 and the directive 93&42/EG for medical applications with CobaltChrome SP2.

Various test methods are used for the quality assurance of materials, starting with the delivery of the base powder, which is examined for its correct chemical characteristics. For AM, the consistent grain size distribution is also checked. A second quality check takes place on the basis of a reference build job, where

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density cubes and tensile bars are manufactured according to fixed criteria under standardized conditions and then analyzed. Further processing and packing takes place once a batch has passed both test levels. A corresponding mill test certificate is included with each delivery and details the test results. This provides customers with comprehensive documentation for their own internal quality management system.

Weilhammer suggested ways to improve the quality of a part. 'First of all, the quality of a part can be improved by applying highest quality standards – and with this the quality assurance EOS applies to the previously mentioned key factors of system, material and process,' he said. 'Other factors can contribute to an improved part quality. We are offering initial and intermediate learning courses for system operators to prepare them for the operation of a highly complex process that is still relatively new for a lot of customers; ensuring regular maintenance services are offered to ensure constant system quality; and taking advantage of consulting services to support further process optimization for a particular application.

'The layperson, i.e. the operator, should be trained initially and on a regular basis to get a deep understanding of the technology and its key factors. The more experienced a system operator is, the better he or she can control the quality of a part.'

However, according to Weilhammer, quality improvement must be in the process rather than the material. 'Powder metal does not need to be changed,' he stated. 'EOS normally uses materials that are already available on the market for conventional manufacturing processes and which customers want to use because they are used to it and need it for their application.'

But specification is important. 'The material then needs to be specified to the AM process, which means that the powder created needs to hold a particular grain size distribution, etc. to ensure that it can be processed on our AM systems. Once the material is optimized it is of course then quality assured before the customer receives it.'

Accompanying standards

Key to quality assurance is 'reliability and reproducibility,' Weilhammer noted. 'Part quality is determined by reliability and reproducibility within one build job, between jobs and between machines. Monitoring during building ensures that the key process variables are within their limits (e.g. oxygen level, *z*-axis height, laser power measurement, melt pool, etc.).

'Generally speaking, the full qualification for the customer is currently done via factory acceptance tests. However, with the technology more and more moving into manufacturing applications we see a growing demand from the market for accompanying standards. EOS actively supports this by participating in the most demanding standardization organizations.'

EOS; www.eos.info

Current additive manufacturing standards

This is a list of current or upcoming standards covering metal AM. It is not intended to be a comprehensive list.

ASTM

ISO/ASTM52915–13 Standard Specification for Additive Manufacturing File Format (AMF) Version 1.1
F2924 – 14 Standard Specification for Additive Manufacturing Titanium-6 Aluminum-4 Vanadium with Powder Bed Fusion
F3001 – 14 Standard Specification for Additive Manufacturing Titanium-6 Aluminum-4 Vanadium ELI (Extra Low Interstitial) with Powder Bed Fusion
F3049 – 14 Standard Guide for Characterizing Properties of Metal Powders Used for Additive Manufacturing Processes
F3055 – 14a Standard Specification for Additive Manufacturing Nickel Alloy (UNS N07718) with Powder Bed Fusion
F3056 – 14e1 Standard Specification for Additive Manufacturing Nickel Alloy (UNS N06625) with Powder Bed Fusion
F2971 – 13 Standard Practice for Reporting Data for Test Specimens Prepared by Additive Manufacturing
F3122 – 14 Standard Guide for Evaluating Mechanical Properties of Metal Materials Made via Additive Manufacturing Processes
ISO/ASTM52921 – 13 Standard Terminology for Additive Manufacturing-Coordinate Systems and Test Methodologies

ISO

ISO/TC 261/JAG – ISO/TC 261 – ASTM F42 Steering group on JWG activities
ISO/TC 261/WG 1 – Terminology
ISO/TC 261/AG 1 – Coordination Group on JG activities
ISO/TC 261/AHG 1 – Naming of standards
ISO/TC 261/WG 2 – Methods, processes and materials
ISO/TC 261/WG 3 – Test methods
ISO/TC 261/WG 4 – Data and Design
ISO/TC 261/JG 51 – Joint ISO/TC 261-ASTM F 42 Group: Terminology
ISO/TC 261/JG 52 – Joint ISO/TC 261-ASTM F 42 Group: Standard test artifacts
ISO/TC 261/JG 53 – Joint ISO/TC 261-ASTM F 42 Group: Requirements for purchased AM parts
ISO/TC 261/JG 54 – Joint ISO/TC 261-ASTM F 42 Group: Design guidelines
ISO/TC 261/JG 56 – Joint ISO/TC 261-ASTM F 42 Group: Standard Practice for Metal Powder Bed Fusion to Meet Rigid Quality Requirements
ISO/TC 261/JG 57 – Joint ISO/TC 261-ASTM F 42 Group: Specific design guidelines on powder bed fusion
ISO/TC 261/JG 58 – Joint ISO/TC 261-ASTM F 42 Group: Qualification, quality assurance and post processing of powder bed fusion metallic parts
ISO/TC 261/JG 59 – Joint ISO/TC 261-ASTM F 42 Group: NDT for AM parts

DIN

DIN NA 145-04-01AA Additive Manufacturing

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