High-precision layer work

MBFZ toolcraft GmbH uses ZEISS 3D ManuFACT for holistic quality control in additive manufacturing.
3D metal printing in action: The laser melts metal powder, after solidification a thin metal layer remains. Thousands of such layers pile up to form the finished component.

Toolcraft uses 3D printing for geometries that could not or only with difficulty be produced with conventional methods. The process brings new challenges for quality assurance.
Additive manufacturing is an uncharted territory for many companies, but not for MBFZ toolcraft GmbH. The company in Georgensgmünd, Southern Germany, manufactures high-end precision parts for the aerospace, automotive, medical technology and semiconductor industries, among others, and since 2011 also parts using 3D printing. The young established production technology is a challenge for quality assurance. Toolcraft is mastering this challenge with ZEISS 3D ManuFACT, the only solution on the market for continuous quality assurance in additive manufacturing.

Heat, noise, the smell of oil: They belong to industrial manufacturing like Yin to Yang. Yet this is quite different in the glass hall at toolcraft in Georgensgmünd. Anyone who has access to the area with their employee ID card hears nothing. They smell nothing either. There are few reminders of factory life as we have known it for a hundred years, because parts are not manufactured the way they have been for a hundred years. Instead of peeling the mold out of cast or forged metal blocks by drilling, milling and turning, additive manufacturing comes at the process from the other way.

Through small windows on the twelve 3D printing machines at toolcraft, you can watch glistening laser beams dancing over a wafer-thin layer of metal powder. Where the spot of light hits, the powder melts in a flash and immediately solidifies again, followed by the next layer. Thousands of hair-thin layers are used in 3D laser melting to create „impossible“ components that could never be produced with traditional subtractive manufacturing. Whereas ten years ago only prototypes and design studies were produced by using additive manufacturing, manufacturers of aircraft turbines, racing cars or medical equipment are increasingly incorporating them directly into their series products.
“Quality assurance in additive manufacturing is a major challenge and it is reassuring to know that ZEISS is an experienced partner at our side.”

Christoph Hauck, Managing Director MBFZ toolcraft GmbH

Challenges for quality assurance
As always, when a new technology emerges in a market, there are always questions. One of them is quality assurance. Jens Heyder points to a monitor that shows two images taken with the ZEISS Axio Imager light microscope at 50x magnification. On the left you can see a section of a good component. There are no large defects visible, only small pores. The material has an even, homogeneous structure. On the right, there is a cross cut shown, in which blowholes and welding defects are present. The construction process here was not optimal, which is why errors occurred during solidification of the melt.

“Crack formation could occur under high loads,” warned Heyder, who has been working as a material engineer in toolcraft’s materials laboratory for three years. Together with his colleagues, he checks the grain size distribution of the metal powder used. They help to optimize the manufacturing process in such a way that no defects occur in the part during melting and solidification.

However, the materials laboratory is only one component in the seamless quality assurance at toolcraft. Each process step is followed by a test: when a part comes out of the printer, after heat treatment and finally after milling into the final form, before the part is sent to the customer. Not every part is inspected. Random samples are taken according to customer requirements where typical parts only undergo a final inspection. For more demanding customer requirements, such as the aviation industry, 100% inspection is required.

But one thing is for sure: when a part is inspected, it is done on a machine with the ZEISS logo. These can be found in several places in measuring rooms and in production at the company: two microscopes (ZEISS Axio Imager and ZEISS Axio Zoom.V16), several coordinate measuring machines (two ZEISS ACCURA, one ZEISS CONTURA and one ZEISS DuraMax) as well as an optical 3D scanner. Although the latter bears the GOM logo, the company also belongs to the ZEISS family since spring 2019.
Consistent data

Why does toolcraft only use measurement technology from ZEISS? “Because ZEISS is one of our major customers,” smiled Christoph Hauck, one of the company’s three managing directors. Toolcraft supplies high-precision components and assemblies for the optics that ZEISS Semiconductor Manufacturing Technology (SMT) needs for exposure machines in semiconductor production. More accurately, Hauck explained: “The real reason is of course another: ZEISS is the only supplier of measurement technology for the entire process chain in additive manufacturing with complete consistency of the data.”

ZEISS markets this under the name 3D ManuFACT. It combines products from the ZEISS portfolio into a complete solution - from scanning electron and light microscopes, computer tomographs and coordinate measuring machines to optical 3D scanners - under the umbrella of the measurement software ZEISS CALYPSO and ZEISS PiWeb, a scalable IT solution for quality data management.

Hauck has been with the company for 17 years and, according to his own assessment, is the one responsible for opening new markets, technologies and customers. This also includes promoting trust in additive manufacturing among customers, “because every new..."
production technology is first viewed with apprehension, especially when development is so rapid”. As early as 2005, the 42-year-old got into contact with the topic at toolcraft, where he reworked additive parts for aircraft turbines. At that time the quality was “still in need of improvement” and could only be used for prototypes, for gaining knowledge quickly for development. It is different today. The parts that toolcraft supplies to its customers are qualified according to the strict specifications of the aerospace industry or medical technology and are just as efficient and durable as traditionally manufactured parts.

As proof, Hauck shows a stator guide vane that guides the gas flow through a stationary gas turbine. It is absolutely on a par with conventionally manufactured variants, but also has several advantages. For example, the curved shape of the blades, which has been optimized with elaborate simulations, can hardly be machined at reasonable cost. And instead of manufacturing each of the 144 blades individually, a 3D printer always builds 12 as a package. This reduces production costs and later assembly costs.
A segment of the stator blades of a gas turbine under the 3D laser scanner. The blue fringe pattern allows to capture the complete surface of the part in a few minutes.

Tracking down the tensions

However, the procedure makes quality control more difficult. Two older non-ZEISS coordinate measuring machines, located next to two ZEISS ACCURA machines in the measuring room, cannot scan such complex blade geometries. “We use the ZEISS blade software module for this,” said Markus Miehling. The Quality Assurance Manager uses the 3D scanner from GOM to obtain a quick overview of the shape of the blade package.

The scanner throws strips of blue light onto the part, a software calculates the surface from the reflected light and shows deviations from the target shape specified by the CAD data set. Due to the constant heating and cooling during laser melting, stresses occur in the metal which can lead to bending of the part. Heat treatment after pressure relieves these stresses but does not reduce them to zero.
Much of the quality assurance in additive manufacturing is new, and some processes have been specially adapted by the measurement engineers for this purpose. This starts in the materials laboratory, where Jens Heyder develops special etching processes for each material to investigate the grain structure inside the components. Under the microscope, you can see a structure that in many respects differs fundamentally from that of cast or machined components. For example, the grains are elongated and oriented in the direction of construction.

If overheating causes burnt spots on the component surface, these can be examined and documented with the ZEISS AXIO Zoom.V16 light microscope. The materials experts at toolcraft have also developed a method to investigate the grain size distribution and structure of the metal powder. The powder is mixed with an epoxy resin and cured.

Mixing technique: Frederik Mack fills a cup with resin powder, then adds metal powder. After liquefaction, the mixture hardens and is ground to the test specimen.

The grain size distribution of the metal powder is examined with the ZEISS AXIO Imager light microscope on polished test specimens. The test specimens help to optimize process parameters in 3D laser metal melting.
Final tactile inspection
If a customer - from the aviation industry for example - demands that all parts need to be inspected, they are placed on one of the two ZEISS ACCURA machines in the quality assurance room. Additively manufactured parts also require special treatment for tactile measurement. If they come directly from the printer, they are still somewhat rough because of the solidified powder grains. A scanning measurement, where the stylus is in constant contact with the surface, is not possible. Instead, individual points are measured to determine the position of representative points on the part.

If the part passes, it goes into the obligatory finishing process, where cutting technicians turn threads, optimize radii and “refine” surfaces using cutting technology. A scanning tactile sensor can then also be used for the renewed measurement on ZEISS ACCURA. The coordinate measuring machine is equipped with the ZEISS mass technology, which allows a quick change between different sensors. An optical line sensor is also waiting for use in the sensor change magazine.

While the technology is exciting, toolcraft follows the principle: We only manufacture additively those parts that really make sense. Parts that are ordered in large quantities and that can be produced using conventional machining processes are still produced in this way today. This is reflected in the number of work stations: 70 machines are used in toolcraft’s machining production, with only twelve in additive manufacturing. But they already account for a quarter of sales - and the trend is rising. Quality assurance will inevitably be further expanded in the coming years.
The ZEISS 3D ManuFACT portfolio includes devices that toolcraft does not use yet: a scanning electron microscope, for example, or a computer tomograph. Which measuring instruments toolcraft will acquire in the future has not yet been determined, said Christoph Hauck, but it is certain that they will be from ZEISS. "Quality assurance in additive manufacturing is a major challenge and it is reassuring to know that ZEISS is an experienced partner at our side."

Last visual inspection: Markus Miehling (left) and Christopher Buckel inspect the finished stator segment of a gas turbine before it is dispatched.

Indispensable for additive manufacturing: the hall for the machining post-processing of 3D-printed parts at toolcraft.
“ZEISS is the only supplier of measurement technology for the entire process chain in additive manufacturing with complete consistency of the data.”

Christoph Hauck

**ZEISS 3D ManuFACT at MBFZ toolcraft GmbH**

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**MBFZ toolcraft GmbH**

Bernd Krebs founded toolcraft in 1989, literally as a one-man company started in a garage. Today, the company employs around 400 people at its main plant in Georgensgmünd and in mold making in the neighboring town of Spalt, 55 of them are trainees. Usable space and the production area is 14,000 square meters. In addition to the company property, the company has secured an additional 50,000 square meters of land, which are to be developed in the future as business grows. This is very likely, because business is constantly increasing: from 2 million Euro in 2002 to 45 million Euro today.

Toolcraft supplies high-end metal parts for the aerospace industry, for medical technology as well as for the optoelectronic and semiconductor industries. Since the introduction of additive manufacturing in 2011, toolcraft has spent 14 million euros on the technology. The company is a driving force in additive manufacturing in Germany, for example as a partner in the new IDEA research project funded by the German Federal Ministry of Education and Research. Toolcraft Co-Managing Director Christoph Hauck is also Chairman of the Board of the Additive Manufacturing Working Group of the German Engineering Federation.
ZEISS IQS - Application + Success Story

System: ZEISS 3D ManuFACT
Industry: High-End Precision Metal Parts / Engineering
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