Ceramic at its Best: Ceramic Prototype Components can be Quickly Manufactured with 3D-Printing – Laser Makes New Processing Methods Possible

Swiss company maxon is renowned for its drive technology, which has travelled all the way to Mars in various NASA rovers. Its high-tech department for technical ceramic in Sexau near Freiburg/DE is not as well known. Here ceramic components are now also 3D-printed and perfected with lasers.

Fig. 1
maxon has chosen the C900 from 3DCERAM Sinto

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Introduction

"What is even more wear-proof than steel and can be turned into axes and shafts for our planetary gearheads, to make them even more precise and reliable?" This is the question that the people at drive specialist Maxon Motor GmbH asked themselves more than 20 years ago. Stefan Zilm, Head of Business Development & Quality Engineering at the Competence Center CIM/MIM in Sexau knows the answer: ceramic components produced with Ceramic Injection Moulding (CIM), a process that is similar to metal injection moulding.

Today, the company has extensive know-how in the field of technical ceramics. With CIM, components can be series-produced in quantities of several tens of thousands. Yet, in spite of all the experience, and even with the use of state-of-the-art engineering methods such as CAD, finite element calculations and simulations, reality remains the ultimate test that determines whether a new idea is sound, or whether a ceramic part can be produced at all and behaves as planned. The customary path from idea to real ceramic component is long and costly. An expensive mould is needed to create the green compact to be sintered. Subsequently, it is turned and cut, sintered and sanded in work-intensive processes. Stefan Zilm admits: "For a first sample, this is very complicated, it costs a lot of time and money."

Ceramic out of the printer

But there is another option: using the shortcut offered by 3D-printing, which is already well-established for plastic components, and is increasingly also being used for metals. Whereas printing of plastic and metal has been part of industrial production for several years now, ceramic printing is still in the process of venturing from the lab to the factory halls. But the advantages were so tempting that maxon already started pilot tests five years ago, with the aim of getting prototypes of ceramic components to the customers faster – and doing some real pioneering work. Stefan Zilm: "With such a printer, the first two to three development loops can be completed a lot easier and faster."

After intensive market research, maxon decided on a printer from French manufacturer 3DCERAM Sinto, which has been

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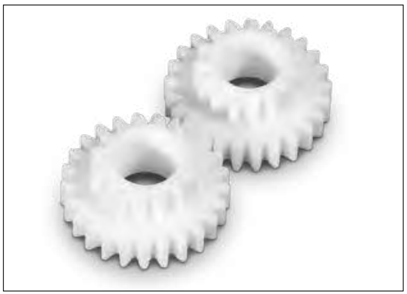

Fig. 2 a–b
Filigree details, fine geometries and hollow structures are made possible by 3D-printing with technical ceramics.

Fig. 3
The new laser machine is maxon's all-round talent, with which quite a few of the machining principles familiar from steel can be transferred to ceramics and virtually any other material

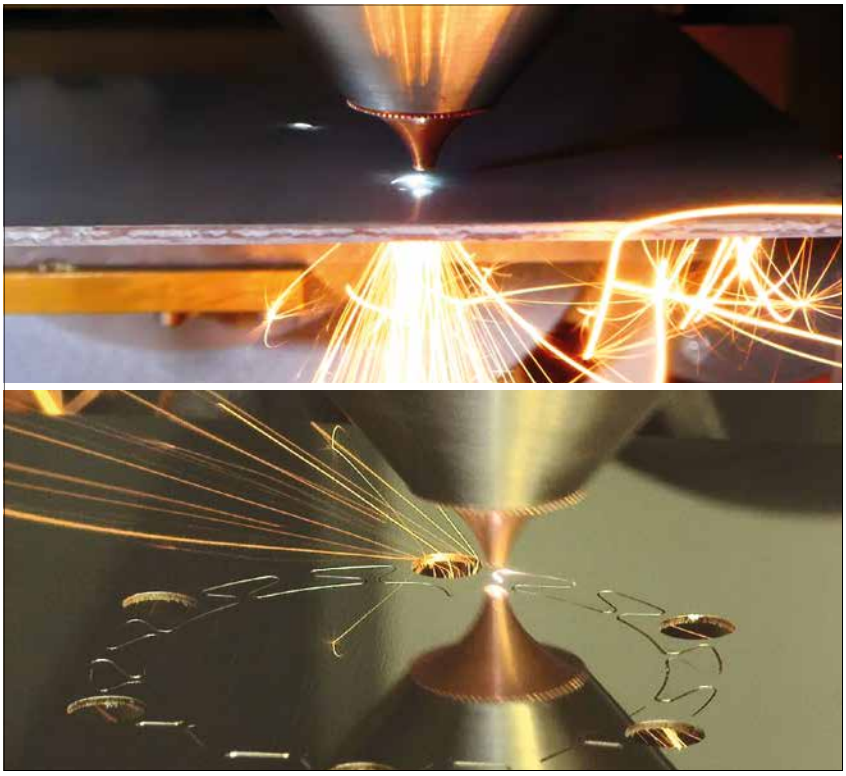

Fig. 4
It is the first machine with this configuration in the free industry *(Figs.: maxon)*

customised to meet the company's own requirements.

"For us, the main selling points were the precision and the rather large printing area of 300 mm × 300 mm," explains Stefan Zilm. The printer is based on the stereolithography method, in which a laser solidifies an emulsion consisting of binder and ceramic powder, and thus constructs a component layer by layer from bottom to top. The layers are between 0,025–0,125 mm thick. After each layer has been applied, the printer bed moves down one step. This ensures even shrinkage during the solidification, as well as high precision and rendering of very fine details. A support structure is not required. The special strength of the 3DCERAM Sinto systems is that it is also possible to create very small parts, with a volume of only 50 mm^3. Depending on the requirements, ceramic components are usually made of zirconium and aluminium oxides. These are the "bread and butter" materials of the technical ceramics field. Both are available as emulsion for the 3D-printer. The debindering and sintering technology corresponds to the CIM procedure, with the result that the green compacts created in the 3D-printer can progress through the same manufacturing systems as the series parts. Depending on the complexity of the desired component and the required tolerance level, small series are also possible and a good alternative to CIM.

According to Stefan Zilm, the procedure does have its limits, due to the diameter of the UV laser beam, which determines which minimum wall thicknesses can be produced. The components are cleaned using compressed air and an additive, to remove excess material from the component. Holes with sizes of 0,5 mm and smaller cannot be made as perfectly round as in injection moulding, but for prototypes, it usually suffices.

Development partners right from the start

Today, the customer simply sends a file in the standardised STEP format (Standard for the Exchange of Product model data) that has become commonplace in 3D-printing, and gets an offer shortly thereafter. Just 10–14 days after the order confirmation, the customer can already hold the first prototype parts in their hands. "In the past, that took several weeks or even months, and involved high mould costs," remembers Stefan Zilm.

Ideally, the customer involves maxon right from the start. “We are development partners from the first idea and can thus influence the design to make it as suitable for ceramics as possible,” explains Stefan Zilm. Thus it is possible, for example, to combine several components into a single component with optimized functionality.
According to Stefan Zilm, such optimizations are very important, considering that the price for a kilogram of the commodities needed for ceramic is around ten times that of steel. “We have to justify this by providing significantly better functionality, for instance through wear resistance, temperature stability or not requiring lubricants.”

Using laser to reach perfection

Where machining reaches its limits, laser steps up to the plate. “We initially purchased the laser for a project whether the tiny components were almost impossible to produce with mechanical means. Today, the laser is our all-rounder with which we were able to apply several principles normally used in steel processing to ceramics – and to practically any other material”, Michael Streicher summarises the benefits of the laser. Michael Streicher heads the Laser Processing D epartment at maxon.
Damage resulting from heat input used to be a concern, until the latest developments in the field of pico- and femtosecond lasers, which can help prevent such damage, became suitable for use in industrial products. maxon’s own system is configured by a commissioned special system integrator. “Here we have found a development partner with whom we were able to cooperate to integrate an additional laser source; to the best of our knowledge, this is the first machine with this configuration in the free industry,” reports Michael Streicher.
It quickly became apparent what new doors the laser can open. The thinner ceramic is, the more elastic it is. “With wall thicknesses of one to two tenths of a millimetre, we can produce tiny solid-state hinges or springs, for example for use in watches.” Independent of the material of the components, the laser can be used to label, engrave and structure them, to selectively remove material, to cut and turn them, and for other modifications.
Michael Streicher and his team are further advancing the development. One example is a project for an own gearhead that requires absolutely vertical walls in processing. In principle, this is where the traditional laser with its conical beam – which is even more pronounced in ceramic than in metal – would normally reach its limits. However, maxon cooperated with the system integrator to apply its know-how to the new laser technologies, with the result that not only vertical walls, but even undercuts are now possible. The method is rather complex, as Michael Streicher describes: “We have an optics box that is comprised of just under 100 optical elements. Some of these can be moved and turned to rotate the beam.” This causes a kind of controlled “tumbling” around the focal position, and, depending on the material, the physical effects involved causes a vertical wall to form. This makes it possible to produce spring-loaded components with a constant cross section or tooth geometries with vertical surfaces, such as those needed in the watch industry. But maxon isn’t resting on its laurels. The development of the laser application is being pushed further – true to the motto: “The sky isn’t the limit and the universe beyond Mars beckons.”