Highest demands on machine and tools

High-precision milling of the hardest special ceramics

BCE Special Ceramics develops and manufactures high-quality precision components from ceramic materials
(Photo: Klaus Vollrath)

"We develop high-precision special ceramic components for use in a variety of demanding tasks in industry, research and medical technology," says Dr. Torsten Weiß, Managing Director of BCE Special Ceramics GmbH in Mannheim. Founded in 1986, the company supplies customer-specific solutions made of ceramic materials, primarily oxide ceramics such as aluminum oxide (Al_2O_3) and zirconia (ZrO_2) or mixed oxides such as ATZ (Alumina Toughened Zirconia) or ZTA (Zirconia Toughened Alumina). In some cases, nitride or carbide materials as well as special compositions are also used.
The developers rely on their extensive materials expertise and a wide range of processes and systems for the production and processing of ceramics. Tailor-made solutions are developed in close cooperation with the customer's R&D deportment. This also includes the production of individual items and prototypes in a relatively short time. Small to medium-sized series are also produced, while large-scale production is subsequently outsourced to appropriate specialists.

In addition to metals, plastics and semiconductors, almost all technical products contain an increasing proportion of industrial ceramics. Ceramics are characterized in many areas of application by their hardness and resistance to heat and cold, wear and corrosion. By selecting suitable materials, their properties can – within certain limits – be flexibly adapted to the respective application. However, until recently, their high hardness prohibited machining except by grinding. A ceramics specialist now machines even sintered aluminum oxide ceramics with a hardness of 1800 HV with µm precision using milling technology.

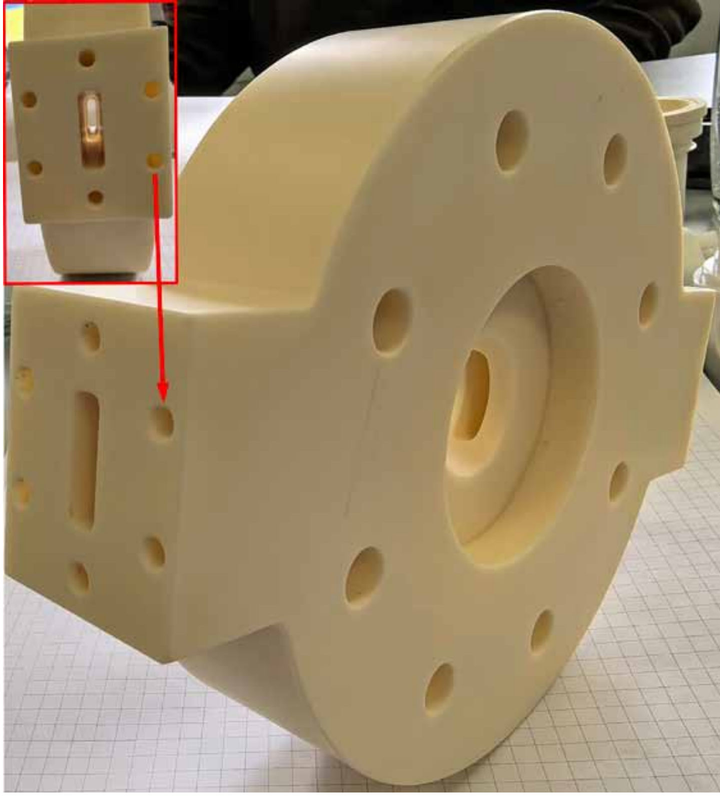
"We also produce prototypes and individual parts from technical ceramics and need processing machines that are both flexible and highly accurate."
Dr.-Ing. Torsten Weiß
(Photo: BCE)

FROM LOOSE CERAMIC POWDER ...

"The first step is to clarify the material issue," adds Dr.-Ing. Torsten Prescher, Application Developer and Sales Manager at BCE Special Ceramics. In addition to the basic material properties, other points such as material pairings with other ceramic components and other materials such as metal or plastic need to be clarified. For example, the conductivity of certain components that are exposed to ionizing radiation is increased by suitable additives just enough to prevent static charges from building up. In other cases, suitable material pairings for use by the customer have to be found.

"The Röders enables us to produce components from sintered ceramics with previously unimaginable geometries and with maximum precision."
Dr.-Ing. Torsten Prescher (Photo: BCE)

Manipulator for ultra-precise positioning of components in micro production
(Photo: Klaus Vollrath)



The "green compact" can be machined without any problems so that it can be extensively shaped. After sintering, this is no longer easily possible.
(Photo: Klaus Vollrath)

Once these initial questions have been clarified, the next step is production: in a first step, BCE manufactures an initial pressed part, on which further machining processes are carried out. The ceramic powder used for this part is mixed with a few percent of an organic binder so that the still fragile ceramic part will have sufficient strength after pressing.

... FIRST A GREENLING IS CREATED ...

"In order to achieve the strength required for initial processing, the pressed part is cold isostatically compressed in a liquid-tight envelope under a pressure of around 2,000 bar," adds Dr. Weiß. The resulting "green compact" already has a certain strength, but can still be easily machined, e.g. by milling, drilling, grinding or thread cutting. When dimensioning, however, it is necessary to work with a considerable oversize of around 20 % linear, as the component will shrink by this amount in all three dimensions during the subsequent sintering process. Mastering the shrinkage behavior during sintering requires a great deal of expertise and experience. If the „as fired" dimensions of the sintered ceramic are not satisfactory, further mechanical processing by grinding i s possible.

... AND FINALLY A HARD-BOILED SINTERED PART

"This has a significant impact on the overall costs, because after sintering, the component has the hardness typical of fired ceramics and is correspondingly difficult to machine," reveals Dr. Weiß. During the firing process, the binder burns away while the ceramic grains are caked into a high-density structure with a pore volume of only around 0.5%. Sintering takes place at temperatures between 1300–1400 °C, and even up to 1700–2000 °C for aluminum oxide. The components then excel by high strength and hardness as well as temperature resistance, but can also withstand very low temperatures down to absolute zero (-273.15 °C) and are resistant to corrosion and to most chemicals.

However, one of their main advantages – high hardness of up to 1800 HV and high wear resistance – has a very negative effect if they have to be machined to size after sintering. Until now, almost the only way to do this was by grinding. Sophisticated technologies are available for this purpose. However, milling to produce complex three-dimensional geometries or free-form surfaces was hardly possible until now due to a lack of suitable machines or tools. The options to design intricate workpiece geometries were correspondingly limited as otherwise extreme production costs would be the result.

During the sintering process, the component shrinks by around 20 % in all dimensions. This must be taken into account beforehand as an allowance.
(Photo: Klaus Vollrath)

The rotor and housing for handling cryogenic liquefied gases must be machined with µm precision.
(Photo: Klaus Vollrath)

Specialist for ceramic machining: Fabian Henning with "his" five-axis Röders RXP 501 DS
(Photo: Klaus Vollrath)

The Zecha ball nose end mill made of diamond-coated solid carbide produced a semi-circular groove 1.5 mm wide and 0.5 mm deep in the upper area of the sintered Al2 O3ceramic
(Photo: Klaus Vollrath)

RÖDERS SYSTEMS FOR MILLING CERAMICS

"In our search for suitable technologies to close this gap, we spoke to companies we knew that already had experience in machining ceramics with Röders milling machines," recalls Dr. Prescher. Systems from market competitors had previously been used for the milling of green parts, but these proved to be unsuited for the high-precision five-axis machining of fired ceramics.

Initial contact with Röders immediately left a positive impression. They were particularly impressed by the fact that key components of the technology, including the control system, were developed by Röders itself and processed on site with the utmost precision. The result are systems that enable maximum contour accuracy. For example, they can be used to machine holes with a roundness deviation of just one µm. They are also so robust that they can withstand the extreme stresses of machining ceramics. This is also made possible by the use of wear-free direct drives, robust linear guides and efficient seals, which effectively prevent the penetration of the highly abrasive ceramic dust or grinding emulsion. According to Dr. Prescher, it was important that the machine could be used in a variety of ways and, depending on the component or operator requirements, it was possible to decide whether to feed the control system with preset CAD/CAM data or to quickly create manual programs. After all, both approaches have their specific advantages.

For this reason, the system was also equipped with a dressing spindle, process monitoring using structure-borne sound and the highly developed grinding cycles of the Röders control system. Internal supply of emulsion at up to 80 bar is used for process cooling and lubrication, which is particularly important when machining with very small tools. Another convincing factor was that there were references of around 50 systems that are already in use for numerous tasks in the machining of ceramics by various users.

Another key point was the availability of suitable tools in view of the extraordinary hardness of the ceramic.

SIMPLE OPERATION AND GOOD SUPPORT

"The operation of the system is so simple and intuitive that we only needed two weeks of training when it was delivered three years ago to be able to work with it and program it directly on the control system," says mechanical engineer Fabian Henning. He had originally worked with Siemens control systems, but the changeover was easy. As he often machines components with simpler 2 to 2 ½ D geometry, he programs a relatively large number of NC sequences directly on the machine. He learned that such tasks are pleasantly easy to implement with the Röders control system, so he can create NC programs for milling or grinding within a short time. For grinding, he often uses predefined cycles from the control. He can simply place these

"NC programs for milling or grinding components with simpler 2- or 2.5-D geometry are easy to implement with the Röders control system." *Fabian Henning*
(Photo: Klaus Vollrath)

over the existing 2D CAD contours or those designed directly on the control. The parameters required for this are retrieved directly from the machining database. In cases where more complex NC programs are required, e.g. for free-form surfaces, he uses the VISI CAM system. This allows him to quickly create corresponding three- and five-axis programs.
The reliability of the machine and the fast response time of the service department should also be mentioned. For example, callbacks were usually made within 1-2 hours. In his three years of using the machine, there has only been one real breakdown due to a defective sensor, and the technician arrived the very next day bringing the required parts with him so that work could resume quickly.

"The decision to purchase the machine from Röders has proven to be an important and successful step towards expanding BCE's processing options while at the same time significantly reducing manufacturing costs," says Dr. Weiß with satisfaction.
Klaus Vollrath, b2dcomm.ch

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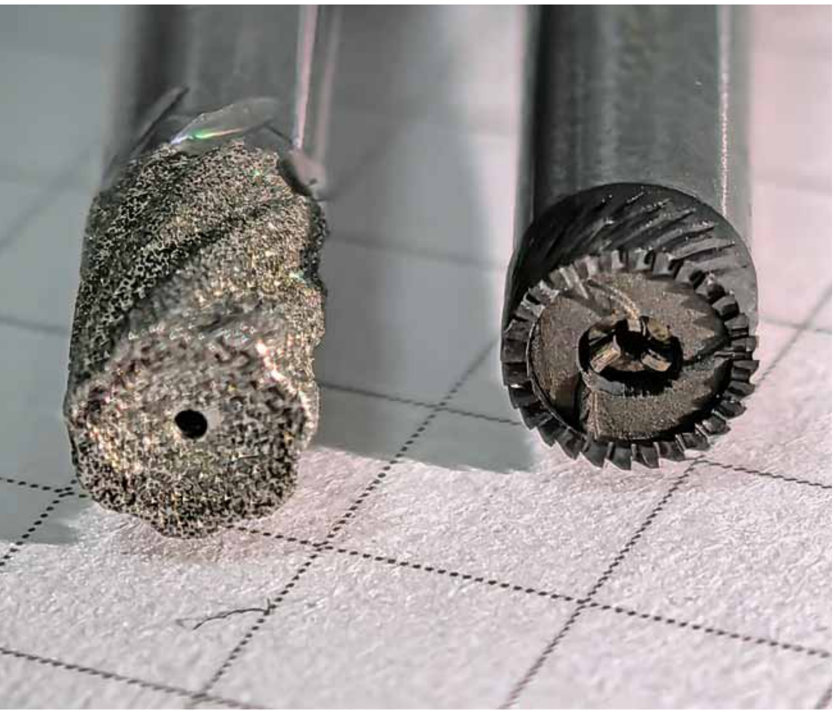

Ceramic-compatible tools from Zecha:
left: grinding tool with metal-bonded diamond grit, right: PCD milling tool with numerous defined cutting edges
(Photo: Klaus Vollrath)

THE RÖDERS RXP501DS/601DSH MACHINE SERIES

The Röders RXP501DS/601DSH HSC 5-axis milling machines have been designed to meet the highest precision requirements while also delivering high cutting performance, even when machining difficult materials such as stainless steel or titanium. They have frictionless linear direct drives which, in combination with 32 kHz controllers in all axes, enable both highly dynamic and high-precision machining. With this elevated correction frequency, a significant reduction in machining time can be achieved while at the same time optimising surface quality.
High-resolution optical scales in all axes are an essential prerequisite for this – at Röders, no compromises are made when it comes to precision. Thanks to its accuracy and dynamics, the machine can also be used for jig grinding.
In addition, the Z-axis is fitted with a patented friction-free vacuum weight-compensation system.

The plants feature a sophisticated temperature management system to ensure maximum thermal stability. The temperature of the medium flowing through all the main system components is controlled with an accuracy of ± 0.1 K. Another special feature is a dedicated control system based on PC technology, the functionalities of which are precisely tailored to the specific tasks of HSC high-precision milling or jig grinding and other grinding operations. As Röders has developed the control system itself, based on industrial PCs and the Windows operating system, updates to both hardware and software are available on request at any time, meaning that the control system of the machines can virtually never become obsolete.
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