Glass, silica glass, ceramics...

Ultra-precise machining of brittle-hard materials

Demonstrator for applications in laboratory diagnostics as well as vacuum technology. The precise microchannels are ground with virtually no breakaways (Photo: ShapeFab)

When processing lenses or other structures made of glass or ceramics for applications such as laboratory and medical technology, measuring devices or laser technology, the "classic" three-pronged technology chain of grinding, lapping and polishing using three different systems dominates. A start-up in Jena now carries out all the processing in one and the same high-precision CNC machine. With certain geometries – e.g. undercuts or free-form surfaces - this offers very interesting advantages. The lot sizes range from single items to medium-sized series.

"Together, Ms. Jahn and I have more than 26 years of practical experience in glass processing for the optical industry," says mechanical engineer Oliver Seidel, Managing Director of ShapeFab GmbH & Co. KG in Jena. The trained cutting machine operator is very familiar with the properties and processing methods of glass and ceramic materials. At the suggestion of Ms. Jahn, who had been thinking about such issues for a long time, both of them gradually developed ideas over the years as to how the machining of brittle materials could be carried out more rationally and efficiently than with the conventional technology chain by using modern, powerful machine tools, such as those routinely used in the metalworking sector. The conventional process chain consists of consecutive grinding, lapping and polishing operations, each carried out on different equipment and sometimes even in different premises. This is not only time-consuming, but also involves the risk of accuracy losses due to repeated changes of clamping. For this reason, they had long been mulling over the idea of performing all three operations in just one setup on one and the same machine tool.

The polished free-form surface on this glass block was produced on a 5axis RXP 501 DS milling machine from Röders using grinding points (Photo: ShapeFab)

Founding Team: Maschbau.-Ing. Oliver Seidel (Managing Director), Maschbau.-Ing. Anett Jahn (Managing Director) and authorized signatory Wirtsch.-Ing. Adrian Helming (f.l.t.r.) (Photo: ShapeFab)

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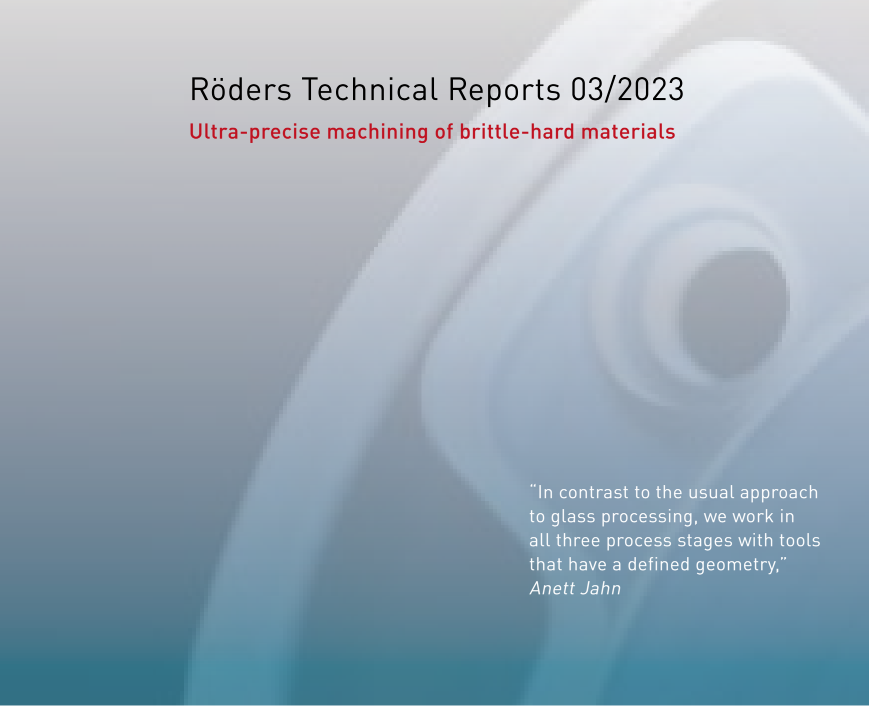


"In contrast to the usual approach to glass processing, we work in all three process stages with tools that have a defined geometry,"
Anett Jahn

Optical sensor produced by grinding with integrated mounting geometries. This enables frameless and micrometer-accurate assembly even without fixtures or adjustment elements (Photo: ShapeFab)

IMPORTANT DIFFERENCES WITH RESPECT TO THE TOOLS

"In contrast to the usual approach to glass processing, we work in all three process stages with tools that have a defined geometry," adds Managing Director Dipl. Ing. Anett Jahn. In conventional glass processing, only the first step is carried out using grinding points coated with diamond grains, which feature a defined geometry. The two following operations, lapping and polishing, on the other hand, are carried out with loose grains, which means that numerous influencing factors have to be taken into account. Lapping is performed with a suspension of uniformly sized unbonded abrasive grains in a narrow gap between the workpiece and a mating tool. Constant sliding relative movements of both bodies ensure that tiny amounts of material are removed. The result is very matt surfaces with a dimensional accuracy down to 0.5 µm and a surface roughness Rz down to less than 0.05 µm. During subsequent polishing, on the other hand, suspensions containing very fine polishing agent grains are guided along the surface under slight pressure using flexible textiles or felts. The aim is to smooth the surface with as little material removal as possible. The surfaces are then extremely smooth, transparent and shiny. In the case of complex geometries or even free-form surfaces, however, these two methods cannot be used without making the process much more complex.

In contrast to this, all operations at ShapeFab are carried out with tools featuring a defined geometry coated with abrasives whose grains are firmly bonded. This has the advantage that the final geometry corresponds exactly to the CAD specification, as is attainable when CNC-machining metals. With specially selected grinding tools, surface qualities of up to 8 nm Ra can be achieved.

A driving force from the very beginning: Anett Jahn has years of experience in programming and operating Röders machining centres (Photo: Klaus Vollrath)

THE STRONG POINTS OF THE SHAPEFAB PROCESS

"The particular strength of our process lies in the fact that we can create structures that are often much more demanding geometrically than those that were previously attainable using conventional processes," explains Adrian Helming, an authorized signatory at ShapeFab. In principle, it has now become possible to create structures with glass that otherwise can only be achieved with metals. Examples include components with 3D free-form surfaces, lens arrays, frameless components with integrated fastening points or holes, microfluidic components for laboratory technology, sensor optics or parts with selectively polished surfaces even in hard-to-reach positions. Since production is highly automated and the parts are manufactured under CNC control and mostly using standard tools, special designs can be produced economically right down to the individual piece. Thanks to the use of modern, high-precision five-axis milling machines with equipment for grinding from Röders, the company has plenty of freedom in the design of complex three-dimensional geometries. This enables the customer to produce components that were previously considered uneconomical to manufacture in this form. High aspect ratios of up to 5:1, pitch deviations of less than 5 µm, dimensional tolerances of less than 3 µm, minimum structural dimensions of 300 µm and surface roughness values Ra of less than 8 nm are achievable. For bores, roundness deviations of only 2 µm are said to be realized even at great depth.

DEVELOPMENT PARTNERSHIP WITH THE CUSTOMERS

"We are dealing with a manufacturing technology that is still new territory for most designers. We therefore support our customers with our special know-how," says O. Seidel. Despite the still small team, this is made possible thanks to the fact that the entire process chain is largely automated. All processes from CAD design to CAM implementation and from processing to quality assurance are fully digitalized. The workpieces are fixed on pallets with a zero-point clamping system from Erowa, which ensures high repeat accuracy, and can therefore be transferred from the machining centers to the coordinate measuring system and back again without loss of precision. The Werth measuring system not only has the usual probes, but also a white light sensor and a fiber probe that does not damage polished surfaces.

Due to several years of intense preoccupation with the processing of glasses and brittle materials using 5-axis processing centers, which started long before the company was created, the founders acquired extensive know-how with respect to systems, software and possible applications. One example are fastening geometries that can be integrated directly into optical parts or free-form surfaces. This allows the components to be joined to the end application with micrometer precision, even without adjustment elements. Furthermore, using five-axis grinding, it is not only possible to create bores in glass, but even threads.

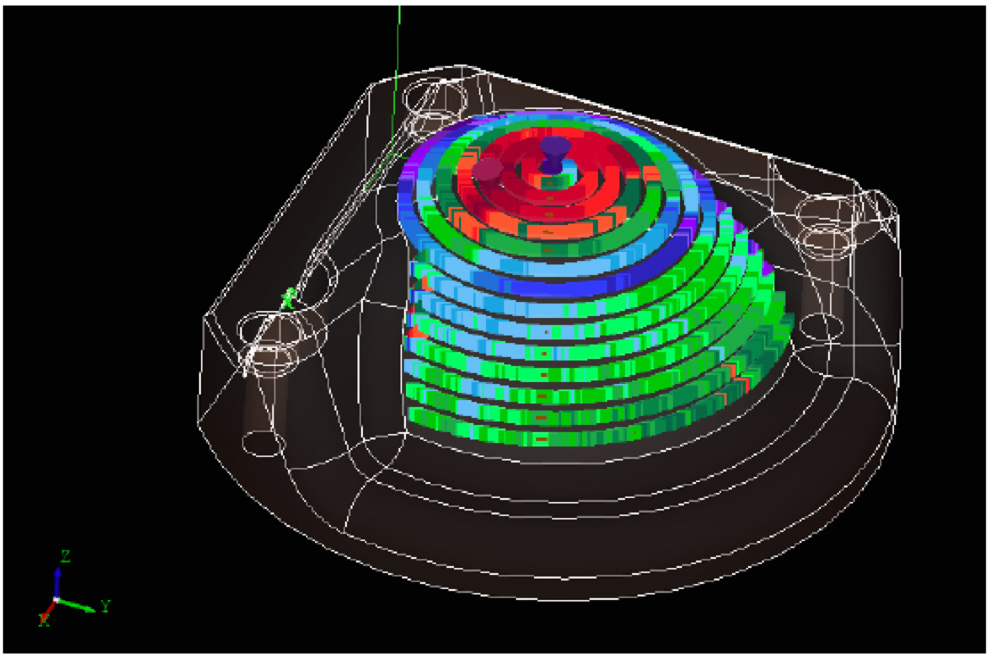
"We are dealing with a manufacturing technology that is still new territory for most designers."
Oliver Seidel

Another advantage for customers is the possibility of using grinding tools shaped to their own designs. For example, undercuts or holes with a more complex geometry are no problem. Likewise, the often problematic production of sharp-edged transitions is also mastered without the edges breaking out.

Thanks to the free combinability of the processing steps, optical viewing windows or coupling points for fibre optics - for example for (Raman) spectroscopy - can be realized selectively (Photo: ShapeFab)

GOOD EXPERIENCE WITH RÖDERS

"We have had good experience with the manufacturer Röders as a partner on the machine side for many years," emphasizes A. Jahn. The collaboration began during an internship that she completed years ago at Röders in connection with her systematic preparation for founding the company. Here she was given extensive additional training in the possible uses and handling of the Röders system and its controls, and she was also supported in implementing her ideas for processing brittle-hard materials. Programming the RMS6 Windows-based control developed by Röders had proved to be intuitive and therefore easy to learn.
It was also easy to implement one's own machining cycles with the RMS6 control system, since it offers extensive functions for powerful programming routines for cases where the existing Heidenhain® cycles are insufficient. This helped her to create her first machining programs very quickly.



The consistent digitalization and automation of production as well as quality control enables useful variants in the display of deviations as well as quick corrections to the process (Graphic: ShapeFab)

A SOLID BASE FOR FUTURE GROWTH

"When starting our company, we paid a lot of attention to thorough preparation and solid financing," explains A. Helming. The team had

systematically prepared for the start-up phase for years. Decisive support was provided by the EXIST start-up grant from the federal government, by the Ernst Abbe University of Applied Sciences in Jena and by active support from Röders. During the course of the internship, the Röders management had recognized the potential of the idea and decided to grant the founders material support. In the difficult initial phase of the start-up, when one would not have envisioned acquiring a machining system, Röders was ready to provide a machine on a rental basis. This enabled the company to supply its first customers very early on, to generate income and build up a customer base, and also to further develop the machining technology. Since then, the company has already been able to purchase a second machine, attract a broad and rapidly growing customer base, and attain a good capacity utilization. "We are particularly confident about the numerous development projects that industrial customers are approaching us with, because we perceive an enormous potential for series applications behind them," says A. Helming with a smile.
Klaus Vollrath, b2dcomm.ch

"We are particularly confident about the numerous development projects that industrial customers are approaching us with."
Adrian Helming

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THE RÖDERS RXP 501 DS

The Röders HSC 5-axis milling machine RXP 501 DS was designed to meet high accuracy requirements while delivering excellent machining performance, especially when chipping hard materials. It has friction-free linear direct drives which, in combination with 32 kHz-clocked controllers in all axes, enable an equally dynamic and high-precision processing. Owing to the high correction frequency, a significant reduction in processing time can be achieved together with optimum surface quality.

An essential prerequisite for this is high-precision optical scales in all axes - when it comes to precision, Röders won't compromise. Due to its accuracy and dynamics, the machine can also be used for jig grinding. In addition, the Z-axis features a patented friction-free vacuum weight balancer.

To ensure maximum thermal stability, the plant has a sophisticated temperature management system. The temperature of the medium flowing through all essential system components is controlled with an accuracy of ± 0.1 K. Another special feature is a dedicated control system based on PC technology, whose functionalities are precisely tailored to the specific tasks of HSC high-precision milling or coordinate grinding. Since Röders has developed the control system itself on the basis of industrial PCs and the Windows operating system, updates of both the hardware and the software are available on request at any time, so that obsolescence of the machines on the part of their control system is virtually impossible. <<