№ 02 | 2024

world of tools

THE HORN MAGAZINE

LADIES AND GENTLEMEN,

one of the most important European trade fairs, AMB, is being held in Stuttgart this year. The precision tool industry expects sustainable economic stimulus from this event. We will be showing you our innovative production technologies and processes for machining applications in Hall 1 Stand 1I10. We will also be exhibiting internationally at the IMTS in Chicago.

The top innovation is the new HORN Supermini. Read in this issue how it pushes the boundaries in large-scale production and learn interesting facts about the 35-year history of this tool system.

In the field of aluminium machining, we will be presenting a new PCD range and also want to take a look at the ever-growing field of additive manufacturing. This manufacturing process differs fundamentally from conventional manufacturing and opens up completely new possibilities for research and industry.

We hope you enjoy reading this issue and look forward to meeting you in person in Stuttgart or Chicago in September.

Markus Horn and Matthias Rommel, Managing Directors of Paul Horn GmbH

world of tools

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SUPERMINI

AN ICON OF TOOL TECHNOLOGY

“This will revolutionise boring,” Paul Horn thought to himself as he closely examined the first prototype of the Supermini. The Supermini system was launched in 1989 and remains one of Paul Horn GmbH’s most successful products to this day. Over the last 35 years, the tool system has undergone numerous stages of development and has solved the challenges of a wide variety of machining tasks worldwide. HORN is now presenting another milestone in the history of the Supermini with a sintered chip breaking geometry for the Supermini type 105. “With a lot of hard work, we have managed to solve economically the problems of long swarf when internally machining small bore diameters,“ says Managing Director Markus Horn.

Boring, profile turning, internal grooving, threading, chamfering, face grooving, drilling and slot broaching. The Supermini tool system can be adapted for numerous machining operations. The solid carbide inserts are used for boring from a diameter of 0.2 mm (0.008“) to around 10 mm (0.394“). HORN developed the carbide blanks of the tool as a teardrop shape. It enables large, precise contact surfaces in the tool holder, which results in greater rigidity of the overall system. Furthermore, the teardrop shape prevents the insert from twisting, which leads to consistently precise positioning of the centre height of the tool. With long tool overhangs, it reduces deflection and minimises vibration during turning. Depending on the application and the diameter to be machined, HORN offers the inserts in three different sizes (types 105, 109 and 110) and different blank types. All types allow internal coolant supply directly to the cutting zone. The HORN tool portfolio contains around 2,500 different standard variants of the Supermini. In addition, HORN solves users‘ machining problems with countless customised solutions.

Chipping problems solved

One of the biggest challenges in internal machining is the generation of long swarf. Depending on the material, boring often leads to ribbons that wrap around the tool, clog holes or, in the worst case, lead to tool breakage. This is where chip breaking geometry can help. It guides and shapes the chip and causes it to break. Previously, specially lasered or ground chip breaking geometries were used for this purpose. However, this increased the cost of the inserts. With the new Supermini type 105, HORN has succeeded in developing a universal boring tool with sintered chip breaking geometry. The tool offers high process reliability due to good chip control. The cutting edge geometry extends far into the corner radius of the insert. It ensures good chip control even with small infeed settings. The geometry can be used universally for different material groups and is suitable for internal, face, copy and back turning.

HORN DEVELOPED THE CARBIDE BLANKS FOR THE TOOL AS A TEARDROP SHAPE.

With the new Supermini type 105, HORN has succeeded in developing a universal boring tool with sintered chip breaking geometry.

In addition to the geometry, HORN has optimised the carbide blanks of the inserts to have greater rigidity and an even more stable cutting edge area. The coolant supply has also been revised. The new insert is compatible with numerous types of 105 tool holder. HORN offers the inserts as standard in three lengths – 15.0 mm (0.590"), 20.0 mm (0.787") and 25.0 mm (0.984") – and in carbide grades TH35 and IG35. The corner radius is 0.2 mm (0.008"). The tool is suitable for use from a bore diameter of 6 mm (0.236"). The wide range of applications for the inserts goes hand in hand with their cost-effectiveness, as the price of the new Supermini is similar to that of the standard insert without chip breaking geometry. The new Supermini has been available from stock since 12th June 2024.

Users can choose the appropriate solution for their application from a wide range of different types of tool holder. These include round shank, square shank, interface and adjustable tool holders for different machine manufacturers. HORN offers four different solutions for clamping the inserts: a classic ball pressure screw, a face clamping element and a lifting element. For confined spaces, HORN also offers a compact system with clamping via a union nut.

HISTORY
HORN Supermini

1989

SUPERMINI SYSTEM

The Supermini system is born and soon becomes one of HORN's most successful products.

1995

EUROPEAN PATENT

A European patent is granted on 11th January 1995.

1998

FIRST PRESENTATION AS SUPERMINI PROGRAMME

The highlight: 1,200 different inserts for just one tool holder.

2007

NEW BORE DIAMETER

The Supermini for boring holes down to 0.2 mm (0.008") diameter sets new standards.

2024

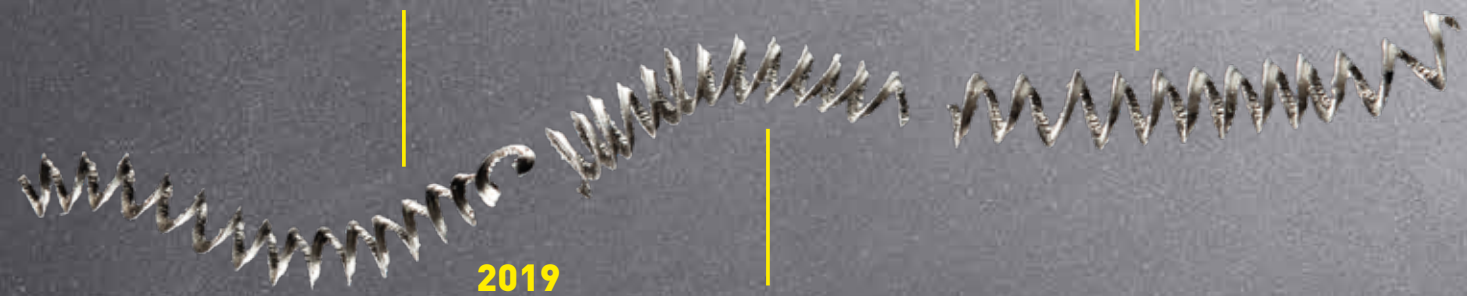
THE NEW SUPERMINI WITH SINTERED CHIP BREAKING GEOMETRY

Pushing boundaries with technology: The Supermini portfolio currently comprises around 2,500 different standard variants.

2016

HIPIMS COATING

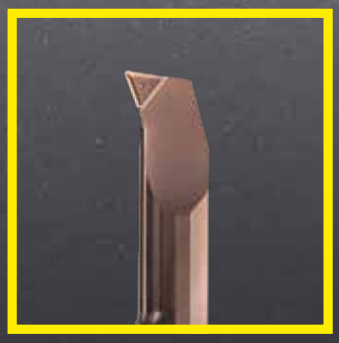
The first Supermini receives a HORN HiPIMS coating.



2019

FRONT CLAMPING ELEMENT

With the new face clamping element, securing the insert from the front of the tool holder becomes possible.



The new Supermini

Economical. Process reliability. Suitable for large-scale production.

SUPERMINI

CHIP CONTROL AND µ-PRECISION

For over 40 years, the brothers Wolfang and Gottfried Rich have relied on precision tools from Paul Horn GmbH. As both a customer and supplier of HORN, RICH Praezision GmbH produces high-quality turned parts for various industries. For boring, the company relies on the new generation of HORN Superminis with sintered chip breaking geometry. "With the new inserts, all chip problems during boring have virtually disappeared into thin air," says Gottfried Rich. The new tool is used for boring the body of the HORN SX interface.

Milling of spanner flats with the HORN DS system.

RICH Praezision GmbH has been a supplier to HORN for several years. The company produces the body of the precision interface for the HORN tool system SX, which is a further development of the 42X type family. The cutter head is connected to the contact surface of the tool body via a stable, robust, yet highly precise thread. This interface offers several advantages: high stability due to the generous thread size, wide support due to the large contact surface and precise changeover accuracy in the µ range, which is always in the centre of the tolerance band. In addition, changing the cutter head is simple and user-friendly. The replaceable head system is mainly used for milling and skiving tools that are brazed onto a tool body made of tool steel.

"Manufacturing the tool holders was initially a major challenge. The precision that HORN requires is very high," explains RICH production manager Wolfram Stiefel. RICH Praezision GmbH manufactures tens of thousands of parts of numerous types for HORN every year. Stiefel relies on HORN tools for producing HORN components. Critical features for the machining are, on one hand, the mating thread and, on the other, several very tight tolerances. In addition, the concentricity and axial run-out of the various contact surfaces are important.

Before switching to the new tool generation, RICH Praezision GmbH often had problems with tangled swarf.

Chipping problems

Several different HORN systems are used for turning the components. RICH generally uses the Supermini system for boring small diameters. In addition to a precision thread, a taper and an additional fit are used for centring the SX interface with µ-precision. A Supermini type 105 is used to turn the taper and the fit. "The turning process for achieving the very tight tolerances is stable. One problem we have always had when boring small diameters is long swarf that wraps around the tool. Everyone has this problem, irrespective of the tool manufacturer," explains Wolfgang Rich.

With the new generation of the type 105 Supermini, HORN has solved the problem that otherwise only lasered or ground special cutting inserts could solve. "With the new Supermini type 105, HORN has succeeded in developing the world's first universal boring tool with sintered chip breaking geometry for machining small diameters," explains HORN technician Frank Blocher. The tool offers a high level of process reliability thanks to its excellent chip control. The cutting geometry extends far into the corner radius of the insert. This ensures good chip control even with small infeed settings. The geometry can be used universally for different material groups.

For internal grooving, RICH Praezision GmbH relies on solutions from the Supermini tool family.

THE CUTTING EDGE GEOMETRY EXTENDS FAR INTO THE CORNER RADIUS OF THE INSERT.

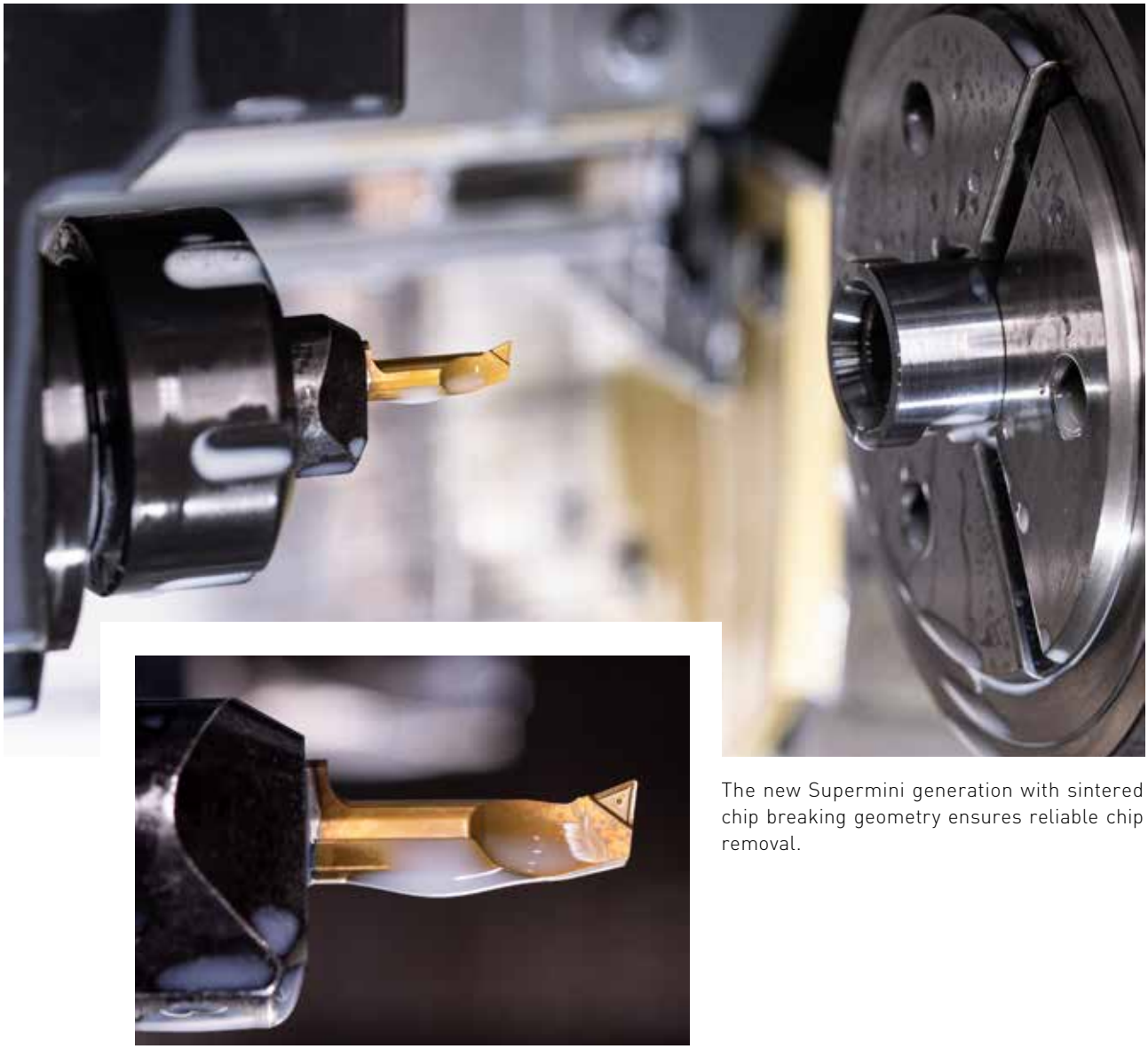
New Supermini generation in use

The advantages of the new system are evident. "The problem of tangled swarf was solved immediately. Whereas we had to manually remove ribbons from the tool with the previous system, the fine chips are barely visible in the swarf bin thanks to the new geometry," says Wolfang Rich. Tool life is equivalent to that of the inserts without geometry. The same applies to the price of the new generation of inserts, which is almost equivalent to that of the comparable inserts without geometry.

High-precision thread milling

Depending on the diameter of the SX body, the HORN circular interpolation milling system or the DC solid carbide milling system is used for milling the internal thread. The inserts are precision ground as a special tool with the bespoke thread profile. The threads are milled in several infeeds. "The thread is checked using a plug gauge that HORN provided us with," says Stiefel. Another type 306 circular milling cutter is used for milling an internal groove. Stiefel chose milling, as the process is more stable than turning due to the unfavourable length-to-diameter ratio. "The circular interpolation milling system with interchangeable cutter head or as a monoblock version can be customised precisely for such milling tasks," explains HORN sales representative Frank Blocher.

HORN's circular interpolation milling system offers the user a number of advantages: It is fast, reliable and achieves good surface finish. The tool, which is guided on a helical path, plunges into the material at a steep or a very shallow angle. This allows threads, for example, to be produced in reproducibly high quality. Compared to machining with indexable inserts for larger diameters or solid carbide milling cutters for



The new Supermini generation with sintered chip breaking geometry ensures reliable chip removal.

A type 306 insert is used for milling the precision thread.

smaller diameters, circular milling is generally more economical. Circular milling cutters have a wide range of applications. They machine steel, special steels, titanium, aluminium and special alloys. The precision tools are particularly suitable for groove milling, helical milling, thread milling, T-slot milling, profile milling and gear milling. They also perform well in special applications such as milling sealing grooves or connecting rod machining.

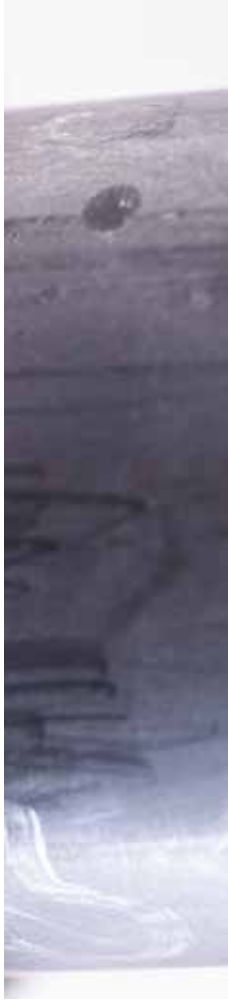
"The new generation of Superminis has shown us once again why we have been relying on precision tools from Tübingen for over 40 years. We are excited to see how the problem solvers from HORN will continue to support us in the future," says Gottfried Rich.

RICH RELIES ON HORN'S TOOL PORTFOLIO FOR CHALLENGING TURNING OPERATIONS.

RICH Praezision GmbH
It all began on 3rd March 1949 with Wilhelm Rich, the grandfather of the current managing directors. In 1986 and 1990, the managing partners Wolfgang Rich and Gottfried Rich joined the company. Today, RICH Praezision GmbH employs more than 40 people. The brothers specialise in the production of precision turned parts and the manufacture of complex workpieces. The assembly of components is becoming increasingly important. According to the motto "Where there's a will, there's a way!", the company manufactures workpieces for numerous industries. Its specialities include components for transmissions, high-quality electrical appliances, hydraulics and pneumatics, and refrigeration.

SUPERMINI

SEALS FOR THE GLOBAL MARKET



Hydraulics, gas and water. Seals are found wherever high pressures are involved or to prevent the tap at home from dripping. The inconspicuous parts are installed in a large number of devices. The Prädifa Technology Division of Parker Hannifin Corporation is a leader in the development and production of sealing solutions. The site in Boom, Belgium, specialises in seals made from machinable materials such as PTFE. The specialists rely on tool solutions from Paul Horn GmbH for machining. The Supermini and Mini systems are mainly used on the machine tools.

"Due to the variety of our different seals, we use special tools 90 per cent of the time. The materials and the different sealing profiles require very sharp tools with special cutting edge profiles," explains Peter Schockaert. He is responsible for production at Parker Prädifa, together with Johan Willems. "HORN's ability to design the cutting edge profiles according to our wishes and requirements is very important to us. That's why we've been relying on the tools from Tübingen for years," says Willems.

Leading supplier of polymer seals

The Parker Prädifa Technology Division's product portfolio includes a wide range of standard sealing elements and sealing systems, customised and application-specific seals and other technical components. Customers include companies from the aerospace, automotive, pharmaceutical, chemical, hydraulics and other industries. The company is recognised as a leading supplier of polymer sealing solutions made from a variety of sealing materials and in a wide range of sizes. This diversity also applies to the sizes of the seals, which range from a diameter of a few millimetres to the world record seal having a diameter of over four metres.

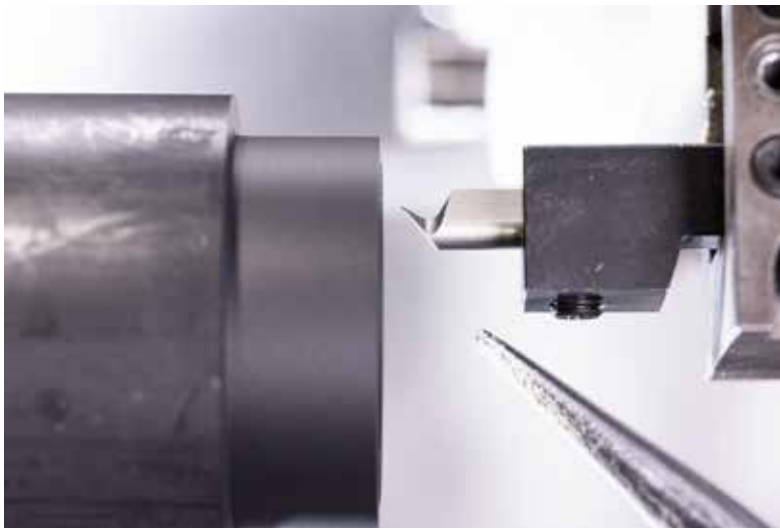
Face grooving and boring are carried out with the Supermini system.

Chips are not produced during machining. The insert of the Superminis cuts or scores the thread into the surface.

"We often just call the tools blades, as they are ground with a very sharp wedge angle," says Schockaert. Such a tool is used in the following application example. An axial thread has to be turned on a steering shaft seal made from a carbon fibre-Teflon material. The thread is needed to make the sealing ring axially flexible. This allows it to be slid over the shaft during subsequent assembly and remain securely attached after it is screwed on.

Razor-sharp blade

The first tests were carried out and orders fulfilled with tools that were ground in-house. "We grind prototypes and small quantities of tools ourselves. Then when volumes increase, we look for an appropriate tool solution," says Willems. In this case, HORN supplied a Supermini with a ground blade for axial machining. The thread to be produced has a depth of 0.2 mm (0.008"). The tool machines the thread at a high feed rate. "At first glance, the machining process looks very easy. But the required absence of burrs demands a very sharp cutting edge," says Schockaert. No chips flow during machining. The Supermini insert cuts or scores the thread into the surface.



Razor-sharp: The wedge angle of the inserts resembles a blade.

THE TOOL PRODUCES THE THREAD AT A HIGH CUTTING FEED RATE.

Tools are mounted in line on a platen for each machining operation.

Micromachining

The Supermini system is also used for producing another plastic seal having a diameter of just under 4 mm (0.157"). In addition to having a face groove, a hole of 1 mm (0.039") diameter must be bored. "The sharpness of the tools is also very important in this application, as the walls are very thin and could warp if the cutting pressure is too high," says Willems. After axial grooving with a Supermini type 105, another Supermini of the same type is used to bore the pre-drilled hole to the tightly toleranced final dimension.

A successful collaboration: Peter Schockaert in conversation with Kees van Bers and Johan Willems.

Mini system in use

Schockaert and Willems rely on special twin-spindle lathes that process two seals simultaneously to achieve high throughput. The spindles are mounted above the tools and the bar feeder for the raw material, which is loaded from above, is in line with a tool carrier. The turning process does not require any tool changes. The tools are permanently mounted in line under the spindles. During the process, the spindles move to each tool in turn until all machining operations have been completed.

A VERY SHORT CYCLE TIME WAS IMPORTANT TO PARKER FOR MACHINING LARGE QUANTITIES.

The Mini system is used alongside Supermini tools. "The Mini system can be adapted very well to the respective machining operations," says HORN technician Kees van Bers. A tool is mounted on the platen for each operation. "With the large quantities involved, a very short cycle time was important to us. The tools allow us to carry out external copy turning, external grooving, face grooving on both sides, boring and parting off," explains Willems.

Parker has been working with tool solutions from HORN for about 10 years. Around 90 per cent of the tools used are special solutions designed specifically for the respective processes. "We are pleased to have HORN as a tool partner that fulfils our wishes and requirements precisely in terms of cutting-edge design," says Willems.

A seal with two axial grooves can be machined in a single clamping.

The miniature seal requires sharp tools.

Parker

Parker is a world-leading manufacturer in drive and control technology. The company develops and designs systems and precision solutions for mobile and industrial applications as well as for the aerospace sector. Almost everything that moves today incorporates Parker technology. To meet the needs of customers, Parker delivers the most comprehensive product range available from a single supplier in the field of motion and control technology. This is supported by expertise in hydraulics, pneumatics, electromechanics, filtration, process control, connectivity, refrigeration and air conditioning, sealing, EMI shielding and aerospace. Parker's products and technologies combine components and systems tailored specifically to customer requirements.

SUPERMINI

INTERVIEW MATTHIAS ROMMEL

Matthias Rommel, who was born on 28th September 1969 in Mössingen, joined Paul Horn GmbH on 1st November 2018 as Managing Director for Production and Technology. He completed his degree in mechanical engineering, specialising in production technology, in Stuttgart. He gained over 25 years of professional experience in leadership and executive positions in the tool industry. Before moving to HORN, Rommel was managing director of the linear technology division of a German global corporation.

What were the goals in the development of the new HORN Superminis with sintered chip breaking geometry?
The most important objective was: How can the issue of swarf generation during boring of long-chipping materials be brought under control economically? As a significant proportion of our precision tools are used for this purpose, another goal was to strengthen our core range with the solution, which had to be offered as standard and be compatible with existing tool holder systems. We have achieved all of these goals.

What exactly have been the problems so far?
One problem with long-chipping materials is the formation of tangled swarf, which can wrap around the component, tool holder and insert and risks damage. In addition, bird's nests can form inside the component itself. This means additional effort – usually human effort and wasted time that should not be underestimated.

What does the new process look like?
The sintered chip breaking geometry of the new Supermini not only ensures very good chip control, depending on the material, but also controlled chip breakage and short chips. Cooling has also been optimised. The result impresses me every time: No bird's nests. No stringy swarf. No interruptions due to entangled tool holders. This saves valuable time and reduces unnecessary effort for manual swarf removal.

Matthias Rommel, Managing Director for Production and Technology at HORN.

How time-consuming was the development of the first functional tool?
Some time ago, we invested in the relevant technologies that have enabled us to reach this milestone. It is also important to have the necessary expertise. Despite having the right infrastructure, it took us more than four years to achieve an optimal result.

What are the advantages compared to lasered solutions?
From the manufacturer's point of view, laser cutting of chip breaker geometries is relatively cost-intensive and therefore only suitable to a limited extent for providing tools in large quantities. This type of tool is therefore mainly used for niche applications. With the new Supermini, we are able to provide tools for a wide range of applications and in large quantities – all economically.

What happens next?
We currently offer a universal geometry in three different sizes. Further geometries and dimensions will follow in the foreseeable future. We are continuing to extend our technological lead and offer our customers solutions to tackle problems on the shop floor in a simple and economical way.

The Supermini tool system can be adapted for numerous machining operations.

PREVIEW

AMB

In September 2024 it will be that time again! For over 40 years, the international Who's Who of the metalworking industry has been meeting every two years at AMB in Stuttgart.

AMB is the marketplace where all facets of the latest products, technologies, innovations, services and concepts are presented. Among industry experts, AMB has established itself as the leading trade fair in Europe in even-numbered years. It thus occupies a leading position among the metalworking trade fairs and is one of the top five worldwide.

AMB: An international industry highlight

AMB 2024 hosts a broad spectrum of exhibitors from various sectors within the metalworking industry. From major international corporations to small and medium-size companies, hidden champions and start-ups, visitors will gain a comprehensive overview of the industry's current standing and performance.

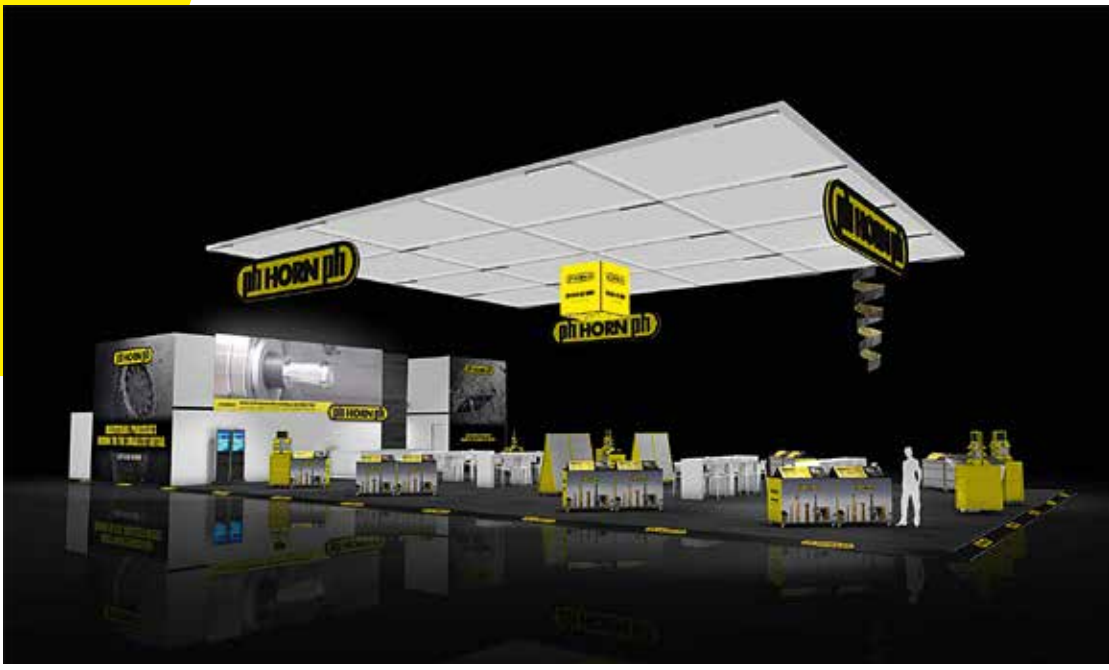
AMB IS ONE OF THE TOP FIVE TRADE FAIRS FOR METALWORKING WORLDWIDE

From 10th to 14th September 2024, the Stuttgart fairground will once again be the focal point of the metalworking industry: AMB – the international exhibition for metalworking – will open its doors. The world's leading manufacturers of metal-cutting machine tools and precision tools as well as many other companies involved in the manufacturing process chain will show what they have to offer. Whether for mechanical engineering, the automotive industry, medical sector, tool and mould making, aerospace or industry generally – users in the metal cutting business will find an attractive range of innovations and technologies at the packed Stuttgart exhibition centre. Exhibits will include modern machine tools and production systems, controls, drives and CAD/CAM, comprehensive automation solutions, the associated measurement technology and Industry 4.0 solutions, collaborative robotics and even artificial intelligence.

Paul Horn GmbH will be showcasing precision tools, solutions and innovations on a stand of approximately 500 m². "One of our absolute AMB highlights is the new Supermini with sintered chip breaking geometry for boring. The geometry ensures ideal chip control and chip breaking. In the area of rotary tools, we will be presenting an extensive range for aluminium machining," says Markus Horn, Managing Director of Paul Horn GmbH. HORN will also be demonstrating many solutions live under power on four machines in Hall 1 Stand 1I10. Markus Horn: "Visit us and let us convince you of our expertise."

PREVIEW

IMTS



At IMTS – International Manufacturing Technology Show – developers, manufacturers, vendors and drivers of manufacturing technology come together to exchange ideas and vision. Visitors will discover advanced manufacturing solutions that include innovations in CNC machining, automation, robotics, additive manufacturing, software, maintenance and transformative digital technologies. IMTS is supported by AMT – The Association for Manufacturing Technology – and is the largest trade show and marketplace for manufacturing in the Western Hemisphere. With over 1.3 million square feet of exhibition space, the show attracts people from more than 110 countries. IMTS 2022 boasted 86,307 registered visitors, 1,816 exhibiting companies, over 7,600 attendees at educational sessions and a student summit that introduced the next generation to manufacturing. IMTS 2024 will take place from 9th to 14th September 2024 in Chicago, USA.

More than 1,200 exhibitors from manufacturing industry will showcase their products and solutions across 1.3 million square feet of exhibition space at McCormick Place. In order to optimise visitors' time at the trade fair, the organiser has divided the exhibition areas into different sections according to industries, technologies and solutions.

IMTS IS THE LARGEST TRADE SHOW AND MARKETPLACE FOR MANUFACTURING TECHNOLOGY IN THE WESTERN HEMISPHERE.

Tools and clamping technology at IMTS

No industry functions without tools. Visitors can noticeably and easily optimise their machines and systems by investing in the latest tools and clamping device technologies. Visitors who prioritise productivity and cost efficiency should visit this area. Mike Csizmar, Chief Marketing and Sales Officer at HORN USA: "Visit us in Chicago. We have ground-breaking technologies – our new Supermini with sintered chip breaking geometry, as well as our new PCD tool range with a focus on aluminium machining."

IN PRACTICE

COUPLINGS EXPERTISE

Transmitting torque, separating and reconnecting power trains: These would be inconceivable without clutches and brakes. Inconspicuous but indispensable, they ensure the mechanical movement of everyday life. This is made possible by Maschinenfabrik Mönninghoff GmbH. The company specialises in the development and manufacture of clutch and brake systems for numerous industries. The team, led by Production Manager Timon Lubek, relies on precision tools from Paul Horn GmbH to manufacture the individual components. In addition to turning tools, HORN skiving tools show their mettle in daily use and ensure high-precision gear cutting.

There are countless types of clutches. The selection depends on the application and the conditions. Basically, clutches can be divided into two categories: engageable and non-engageable. The primary function of a clutch is to transmit torque between two shafts. Other functions include compensation for misalignments, damping of torque at irregular speeds, and predetermined breaking points for overload protection. Furthermore, clutches can be differentiated according to the type of torque transmission. They may be friction connections, which are used for slipping clutches in cars, for example, whereby two or more discs are pressed together with spring force or hydraulically. Alternatively, interlocking clutches transmit force via gears, fingers or other means.

Clutch/brake combinations for ski lifts

Maschinenfabrik Mönninghoff offers a wide range of products, including electromagnetic tooth clutches for precise torque control and disc clutches for demanding applications. The company also develops electromagnetic holding brakes for safe and fast stopping, as well as overload clutches that trigger when a defined torque is exceeded to protect machine components from damage. Maschinenfabrik Mönninghoff manufactures clutch/brake combinations that are used, for example, in ski lift and gondola systems from well-known manufacturers. The products ensure that gondolas are automatically engaged and disengaged in the upper and lower stations and travel through each station at the same distance from one another. This ensures that people are safe when

The disc carrier is used in a clutch/brake combination.

Maschinenfabrik Mönninghoff relies on DMG MORI turning/milling centres with exclusive technology cycles.

getting on and off, despite high cable speeds. Some toothed components such as disc carriers are used in these products.

Maschinenfabrik Mönninghoff relies on the gear skiving process for the production of disc carriers. Tool systems from HORN are used for this purpose. "In addition to the performance of the tools, we were impressed by HORN's technical support. A few years ago, HORN joined our ranks as our third supplier of skiving tools. At the time, we were surprised at the technical questions the HORN designers had for us regarding tool design. We hadn't been asked that by the other suppliers before," says Lubek. HORN's technical expertise convinced Lubek and his team. "We have created a separate area in our design department that only deals with the design of gear cutting tools," adds HORN sales representative Michael Ehmann.

Tools in use

Today, over 20 different types of skiving tool are in use on the machines at Maschinenfabrik Mönninghoff. The modules to be produced range from 0.5 to 2.5. Gear skiving of the disc carrier for the ski lift clutch with a module of 2 is performed by a tool with an interchangeable head. The type WSR solid carbide cutter head is connected to the tool holder via a precision interface. During the cutting process, the tool produces the gear form in 7 individual strokes. These are divided into 6 roughing strokes and one for finishing. The individual infeed settings are not linear, but average around 0.45 mm (0.018"). "Thanks to the HORN skiving tools, we are at a high level when it comes to the quality of the gears we produce. Due to this and the technical support, HORN is our go-to supplier for gear skiving tools," says Lubek.

"THANKS TO THE QUALITY AND THE TECHNICAL SUPPORT, HORN IS OUR FAVOURITE FOR GEAR SKIVING."

The HORN gear skiving system includes tools for the highly productive machining of internal gears, splines and other internal profiles as well as external teeth without interference. The most important advantages of gear skiving in these applications are the significantly shorter cycle times compared to gear broaching, the ability to use the tools on optimised turning/milling centres, turning and gear cutting in a single clamping, and the elimination of undercuts at the base of the gear teeth. In addition, the usually more productive and cost-effective production process compared to gear shaping and broaching and the four to five times shorter cycle time compared to slotting are compelling. This also applies to the possibility of hard machining gears into solid material. The skiving tools are designed for gear cutting medium to large batches. Each tool is individually adapted to the application and the material to be machined, with the different tool interfaces being based on the number of teeth and the module.

Even for larger modules

Especially for internal gears, HORN stresses the advantage of short cycle times for larger modules. The gear skiving of these bigger sizes requires large and rigid milling/turning centres that enable the appropriate synchronisation between the workpiece and tool spindles. The larger the module, the more critical is machine rigidity. This issue can be mitigated in respect of the tool by dividing the inserts between the left and right hand flanks. After gaining experience with small solid carbide skiving tools, HORN used this expertise to cover larger modules as well. Its technicians check the feasibility of each application before implementation and discuss the tool design and recommendations for the process with the user.

The system includes cylindrical or tapered tools for modules from 0.5 to 2. The solid carbide monoblock type is available with a diameter of up to 20 mm (0.787") and in a slim design. It is used for small modules and small components, preferably when a slim shaft is required due to the risk of collision. The grades and coatings customised to the application produce high surface quality on the workpiece. Skiving tools with a replaceable head system are used for tool diameters over 20 mm (0.787"). The precise interfaces allow the cutting head to be easily changed inside the machine without removing the tool holder. The carbide tool holder ensures high rigidity, wear resistance and precision. For the larger modules, HORN recommends using a tool with indexable inserts. For the WSR tool type in particular, HORN offers the option of placing the internal coolant supply in front of or behind the insert. This allows blind holes, through holes or stepped holes to be machined with appropriate coolant delivery, depending on the application.

HORN technicians check every skiving application for feasibility and discuss the tool design and recommendations for the process with the user.

The HORN gear skiving system includes tools for the highly productive manufacture of internal teeth, splines and other internal profiles, as well as external teeth without interference.

A good collaboration: Timon Lubek in conversation with HORN technician Michael Ehmann and Mönninghoff employee Yavuz Kol.

Maschinenfabrik Mönninghoff uses a machine from DMG MORI for gear skiving ring gears. "With the CTX beta 1250 TC, we have a flexible machine with user-friendly technology cycles, such as gearSKIVING 2.0, on which the skiving processes run reliably," explains Lubek. Before the gear skiving process was introduced, Maschinenfabrik Mönninghoff relied on gear broaching and milling. The switch to gear skiving brought many advantages: Time savings and high precision as well as the quality classes of the gears and the ability to produce components completely on one machine. Complete machining increases accuracy, as tolerance is more difficult to achieve with each new clamping. This plays a particularly important role in the production of components for clutch/brake combinations.

THE PRECISE INTERFACES MAKE IT EASY TO CHANGE THE CUTTING HEAD IN THE MACHINE WITHOUT REMOVING THE TOOL HOLDER.

Successful collaboration

Maschinenfabrik Mönninghoff has been working with tool systems from HORN for over 25 years. "In the beginning, we only used the little horns, as we always call them, for turning," jokes Lubek when talking about the HORN Superminis." He continues: "We now rely on HORN's broad tool portfolio. Their expertise in tool technology and the prompt delivery have convinced us."

Mönninghoff machine factory

From aviation to marine, from delicate high-tech robotics and packaging machines to pumps and extruders: Reliable drive technology is required when forces need to be transmitted. The technical requirements that the products must fulfil are as varied as the areas of application and use cases. Maschinenfabrik Mönninghoff is a reliable and innovative clutch manufacturer and technology partner, able to fulfil customer-specific requirements precisely. The switchable couplings, shaft connections, overload systems, linear technology and integrated drive systems are used worldwide in a wide range of variants in machines and systems in all industries.

IN PRACTICE

ALUMINIUM AND ALUMINIUM ALLOYS

Aluminium (Al) is found in the Earth's crust in mineral form. The most important raw material for its extraction is bauxite. Pure aluminium oxide is extracted from this rock in a complex and energy-intensive production process. The oxide is then dissolved in a melt and electrolysed.

PROPERTIES OF ALUMINIUM

- Density about 1/3 of steel (lightweight construction, energy and cost savings)
- Chemically resistant (food and beverage industry, offshore sector)
- Good formability, weldability and castability (engine, car and aircraft parts)
- Decorative and abrasion-resistant surfaces (industry, household, office)
- High electrical conductivity (cables, overhead lines)
- Non-magnetic

Success story

The demand for aluminium is increasing every year. Many applications and developments require a lightweight yet stable material – requirements that aluminium can optimally fulfil. The material is also extremely versatile. Accordingly, aluminium can be found in many areas from packaging, building materials and transport to mechanical and plant engineering. Virtually loss-free recycling increases the long-term benefits of aluminium in a product's life cycle. The production, processing and use of aluminium is an international process, starting with the extraction of the raw material through to processing into beverage packaging or car bodies. Aluminium manufacture combines expertise from many parts of the world to create a multifunctional material with outstanding sustainability.

(Source: aluminiumdeutschland.de)

Machining of aluminium

The tensile strength, elongation, hardness and yield strength of aluminium can be influenced by alloying elements such as silicon, magnesium, copper, zinc and manganese. The material can become soft during machining due to heat development, stick to the cutting tool and even destroy it due to disrupted chip flow. It is therefore important that the material and cutting parameters are properly matched. It depends on the aluminium alloy, the cutting tool, the cutting feed rate and speed, as well as the type and quantity of coolant.

Aluminium – a versatile material that is used in all sectors of the economy.

HORN tools for machining aluminium

The most important features of HORN's wide range of standard and special tools are special chip breaking geometries with sharp inserts, polished rake faces and coatings with very good anti-friction properties to counter the strong adhesion tendency of aluminium. Carbide inserts for grooving are ground peripherally to ensure extremely sharp inserts. For machining aluminium alloys with a high silicon content, the inserts are coated. The portfolio includes coated and uncoated circular tools and solid carbide cutters for milling. Single-edged milling cutters with a large chip space are also available for rapid metal removal rate based on high cutting data. Ultra hard cutting materials such as PCD and CVD-D with precision-lasered cutting edges are available for long service life or more complex work. MCD-tipped tools are used for high-polish machining of reflective surfaces or aluminium blow moulds, for example.

In manufacturing, aluminium alloys are among the easiest materials to machine. Nevertheless, cutting this soft metal can quickly become a challenge. Adhesion, built-up edges and chip jamming can lead to tool breakage. With the right tools, grades, cutting data and the correct amount and type of coolant, aluminium alloys can be machined with reliable results. Drilling, reaming, grooving and milling: HORN offers a broad portfolio of optimised tools for economical machining of the light metal. Polycrystalline diamond (PCD) is also very suitable for machining aluminium alloys due to its smooth surface, low tendency to adhere and high wear resistance. Moreover, the sharp cutting edges result in high surface quality. In addition to turning, the grade is also used for drilling. Due to the high cutting parameters that can be achieved, PCD-tipped drilling tools enable a shorter cycle time and longer tool life compared to solid carbide drills. PCD drilling tools are often used in series production, for example when drilling aluminium wheel rims. The situation is similar for drilling and milling. At AMB, HORN will be presenting a completely new range of PCD milling tools specially designed for machining aluminium.

HORN OFFERS A BROAD PORTFOLIO OF OPTIMISED TOOLS FOR THE ECONOMICAL MACHINING OF LIGHT METAL.

PCD MILLING PROGRAMME FOR ALUMINIUM MACHINING

Thanks to over 30 years of experience in the development and production of precision tools made from ultra-hard cutting materials, HORN offers a comprehensive range of PCD milling cutters for productive machining of aluminium. During this time, HORN has proven itself in numerous industries - and has thus become an important partner in the field of PCD tools. Based on market experience and customer requirements, HORN has methodically developed a complete standard programme of milling tools. The standard series range DM20 to DM90 enables reliable machining of aluminium, non-ferrous metals and technical plastics. With a focus on resource conservation, customised cutting edge lengths and tool design, the tools are available from stock.

With this product programme, HORN offers a wide range of standard and special tools, from simple PCD end mills to complex and modular combination tools. As a driving force, the focus is on economical, well thought out solutions with high productivity combined with HORN technology, flexibility and reliability. The HORN high-performance PCD grade consists of a sophisticated mixture of diamond grains of different sizes. As the volume percentage of diamond increases, so do the effective hardness, toughness and cutting edge quality. Strict quality standards and their control are a matter of course and ensure strong performance.

PRODUCTS

DM20
The PCD end mills in the DM20 series are universal all-rounders and are suitable for a wide range of applications. The double-edged PCD-tipped milling tools with a central cutting edge cover almost the entire range of machining applications and are universally suitable for non-ferrous metals and non-metallic materials such as engineering plastics. The series is rounded off by a specially adapted body design for dry or wet machining. Different PCD substrates as well as modern and customised technologies for cutting edge preparation ensure productive machining processes, as well as reliably high performance and a long tool life. With a semi-standard tool, HORN also offers the fast and flexible option of customisation to meet specific customer requirements.

DM25
The DM25 product range with cutting edge lengths between 8 mm (0.314") and 18 mm (0.708") is particularly suitable for contour and finishing milling operations on external and internal contours when high cutting feed rates are required. The multi-edge design significantly reduces machining cycle times. While the R series with internal cooling is preferred for non-ferrous metals, the C series with an additional positive rake angle is suitable for machining abrasive materials through to graphite and fibre-reinforced plastics.

DM27
Modern fibre-reinforced composites are lighter, stronger and more stable - which is why they are becoming increasingly important for industrial applications. When machining these abrasive materials, the focus is on the quality of the component edges. Fraying, delamination or chipping create a demanding requirement profile for tool geometry and grade in order to be able to control these component-specific and wear-related conditions. The risk of vibration on thin-walled components or when trim cutting panels, taking into account down or up milling options, represents an additional consideration for stable milling. With a positive-negative insert arrangement, coupled with internal cooling and a centre cut, the tools in the DM27 series offer a coordinated overall package for universal milling applications.

HORN HAS MATURED INTO AN IMPORTANT PARTNER IN THE FIELD OF PCD TOOLS.

DM30
Milling tools in the DM30 series are specially designed for cutting tall components. The PCD-tipped milling tools in a spiral design impress with their smooth, paring cutting action . The segmented design reduces cutting forces and machining noise. The precise positioning and arrangement of the PCD inserts ensures high surface quality and milling results without burrs. The tools are suitable for peripheral milling, trimming or circular milling operations and can be used at small to medium infeed depths as well as for finishing operations with maximum utilisation of the cutting edge length. The cutting edges are high quality and burr-free.

DM33
Components made from high-strength and forged aluminium are challenging to machine and place stringent demands on the tool. In contrast to classic aluminium die casting, extruded and forged aluminium causes long chip formation due to the lack of silicon and a compressed material structure. In addition, there are built-up edges and above-average stress on the tool. With the DM33 series, HORN offers a customised milling concept. Whether for face milling or ramping: the tools are designed to produce bores or pockets by helical entry into solid material without pre-machining and with high infeed values. Holes, cut-outs, pockets or profiles can be produced reliably and economically using tools of 12 mm (0.472") to 16 mm (0.630") and 20 mm (0.787") diameter. The tools are designed with a central coolant channel and offer reliable chip flow even during deep machining operations. For larger bores, larger screw-in diameters are available in the DG-V series in conjunction with tool holders of various lengths.

DM50
With the DM50 series, HORN offers a tool concept that is a well thought-out solution in terms of wear, flexibility and cost-effectiveness, especially for universal applications and those that require optimal cycle times. The main wear zone of the head and inserts can be replaced – including an individually replaceable intermediate sleeve that enables different cutting heights. The system therefore offers a tool solution that can be flexibly customised to any application, while at the same time focusing on operating costs and service costs. Thanks to its high level of versatility, the tool system can be converted quickly to different corner radii and corner chamfers with the desired cutting height . The combination of inserts on the face and periphery in a 2:1 ratio is tailored to different application requirements and milling techniques. Precise positioning on changeover without any offset guarantees accurate milling results. The design, with an emphasis on the axis angle, enables smooth cutting and high surface quality.

HORN'S HIGH-PERFORMANCE PCD GRADE IS MADE UP OF A SOPHISTICATED MIXTURE OF DIFFERENTLY SIZED DIAMOND GRAINS.

DM70
HORN developed the DM70 series especially for face milling. The system enables high efficiency milling and good surface quality in smaller diameter ranges. The precise face and taper contact interface guarantees axial run-out in the µ range. The simple and quick replacement of the PCD-tipped milling cutter onto a carbide body is suitable for lean production processes and automated production systems. The carbide body also offers high stability and guarantees a long service life, even when the inserts are re-tipped several times. The series is designed for stable milling as well as face milling operations in deep structural components due to the availability of large and small cutting diameter variants as well as a short and a long HSK63-A holder. The system offers reliable cooling properties with a sophisticated, screw-mounted coolant distribution system on the face.

STRICT QUALITY STANDARDS AND THEIR CONTROL ARE A MATTER OF COURSE AND ENSURE STRONG PERFORMANCE.

DM90
From face milling or shoulder milling of die-cast aluminium components to the machining of engine or housing components and even the face milling of surfaces of various non-ferrous metals, burr-free machining is essential. Accordingly, PCD-tipped inserts are the benchmark. The DM90 series is specially designed to meet these requirements and deliver high performance. It is available with long or short flutes in diameters from 50 mm (1.968") to 125 mm (4.921"). HORN offers the appropriate tool for these applications, without time-consuming presetting of the inserts. The series is notable for its extremely smooth running and axial run-out accuracy in the µ range. Whether for roughing cuts up to a_p = 4 mm (0.157") or for finishing cuts, the system achieves surface finishes of better than R_z 4 µm (0.000157").

HIGHLY PRODUCTIVE DRILLING

With the D1122 solid carbide drilling system, HORN presents a new generation of tools for productive and economical drilling in steel and cast materials. The straight cutting edge is highly stable and reduces the formation of built-up edges. Furthermore, the corner chamfers contribute to wear protection of the cutting edge and thus to a longer tool life. The specially developed in-house HiPIMS coating offers a high level of wear protection for the tool. The open, precision-ground flutes ensure reliable chip removal.

TWO LAND MARGINS ENSURE GOOD STABILITY AND REDUCED FRICTION.

With the new tool system, HORN demonstrates its expertise in the development of drills for demanding machining operations. The solid carbide tools offer an attractive price/performance ratio.

The customised cutting edge geometry demonstrates a high level of process reliability. HORN offers the drills with point angles of 135 degrees and 140 degrees. Two land margins ensure stability and reduced friction. The 135-degree type is available in an 8 x diameter version with four land margins. This offers optimum drilling quality and high positioning accuracy. The 140-degree drill is available in short and long versions (3 x D and 5 x D) in accordance with DIN 6537. The optimised point enables good chip formation and coolant distribution for both angles. All types are equipped with internal coolant supply. The clearly assigned material groups enable the user to select tools easily.

PRODUCTS

DG REPLACEABLE HEAD MILLING SYSTEM

With well over 1,000 customised solutions and numerous standard variants, HORN is demonstrating an economical and resource-saving tool solution with the DG modular replaceable head milling system. With the new tool generation, HORN has optimised the interface between the cutting head and shank for greater versatility, stability and higher changeover precision. This is made possible by the new, solid carbide monoblock design of the replaceable head. It means that the interface and the desired cutting edge shape are precision ground from a carbide blank. The system achieves high precision through a guide pin, a precision trapezoidal thread and a taper/flat contact. The changeover accuracy is in the µ range. This reduces the set-up time and cuts production costs. The modular design allows quick changeover to a different cutting insert and the use of customised special solutions.

THE CUTTER SHANKS ARE AVAILABLE IN SOLID CARBIDE AND STEEL VERSIONS.

HORN stocks the milling system as standard in diameters of 10 mm (0.394"), 12 mm (0.472"), 16 mm (0.630"), 20 mm (0.787") and 25 mm (0.984"). In addition, numerous cutting edge shapes for the most common machining tasks are available from stock. The user can choose an interchangeable head with a cutting edge length of either 0.5 x diameter or 1 x diameter. The cutter shanks are available in solid carbide and steel versions. All types have an internal coolant supply. For economical and productive machining of material groups P and K, HORN offers the new grade RC4P.

ADDITIVE

EMOTIONS AND CRAFTSMANSHIP

Rock ‚n' roll, blues and heavy metal. No other instrument arouses as many emotions among the public as an electric guitar. The instrument plays a central role in most music genres and has characterised generations of musicians since the 1930s. In addition to mass-produced guitars, there are also small craft businesses that perfect the construction of electric guitars down to the smallest detail. Marc Lochner runs one of them. With his company EBG-Instruments, he is breaking new ground, but also holding on to old traditions. For a current project, a Telecaster, 3D printed parts made of titanium and CVD diamond cutters are being used. Locher received support from Paul Horn GmbH for this project.

Marc Locher combines modern technology with craftsmanship.

Critics claim that anyone can build an electric guitar with a saw, a screwdriver and a soldering iron. In theory this is true, but nobody wants to hear it. In contrast to an acoustic guitar, most classic electric guitars do not have a hollow resonator to amplify the sound of the strings. There are some electric guitars that have a hollow body, but the tone is generally influenced by the design, the choice of wood, the hardware, the pickups and the quality of workmanship. Pickups are magnetic coils that convert the vibration of the individual strings into electrical signals. When the guitar is being played, these signals pass through an effects processor and are then boosted in an amplifier and output as sound via a loudspeaker. The playing technique, the effects processor and the amplifier produce the desired and familiar electric guitar sound.

Craftsmanship

With his instruments, Locher impressively demonstrates how to combine the traditional craftsmanship of guitar making with new ideas and technologies. For example, he combines CNC-milled aluminium bodies with fine woods and carbon fibre necks. He builds about six electric treble or bass guitars per year. All instruments are customised according to the customer's wishes and requirements. In his everyday life, Locher works as a vocational school teacher in the field of CNC technology. In his spare time, he can be found in his cellar working on his instruments. He has created a guitar-making area in his basement at home with everything a technician's heart could desire. Housed in two rooms, the workshop has a CNC milling machine, numerous woodworking machines, a paint booth and a workstation for final assembly. His cellar also houses a small treasure trove in the form of a tonewood store. Beautiful and rare tonewoods such as certified ebony, curly maple and mahogany are stored here.

ALL INSTRUMENTS ARE CREATED ACCORDING TO THE CUSTOMER'S WISHES AND REQUIREMENTS.

Milling of M3 internal threads in a printed titanium component.

"I'm always on the lookout for old wooden staircases from the 50s and 60s. In those days, staircases were often made from solid mahogany," Locher explains. He uses the old stairs to make the guitar bodies and necks. "The wood is very suitable for building a guitar, as it is also relatively stress-free due to its age and the dry conditions in the houses," explains Locher. He is also using this valuable wood for his current project, a Telecaster. Its shape is one of the most popular electric guitar designs ever. It was developed by the world-renowned guitar builder Leo Fender. However, Locher's Telecaster is not a simple copy of Fender's guitar. With special materials and components as well as a clean look, and with many hidden screw connections on the front of the guitar, it is a unique piece that requires a lot of time, work and craftsmanship as well as special manufacturing techniques.

3D metal printing

"Building exceptional instruments also requires the use of special materials," says Locher. That's why he decided to use titanium components, including the bridge, which is mounted on the body of the guitar and supports the strings. The bridge is a very important component of the guitar, as it has a major influence on the attack (speed of tone development) and sustain (duration of the tone). Locher approached the 3D printing specialists at HORN with the 3D model he had designed himself to have these parts printed from titanium. Due to the component geometry and the thin walls, milling the parts was out of the question as it would have been too time-consuming and costly. Locher was lucky: HORN had already started its additive manufacturing project in spring 2018. Today, it has become a separate production area. HORN uses additive manufacturing in its own tool production, particularly in the manufacture of

For machining the guitar body, Locher uses a three-axis CNC milling machine with a high-speed spindle and a four-edged, diamond-tipped milling cutter from HORN.

prototypes, specials and tool holders and in the optimisation of coolant attachments. HORN makes the extended possibilities offered by additive manufacturing available to customers and partners such as Locher. Additive manufacturing makes sense if it results in a technological advantage. However, in many cases there is no economic advantage to additively manufacturing a component that was previously produced conventionally. This applies, for example, to turned parts that can be produced quickly on sliding headstock automatic lathes. Additive manufacturing would also be too expensive in terms of rework for finishing.

SLM process

For projects such as Locher's electric guitars, HORN uses selective laser melting, also known as the powder bed process. Metal powder is applied in a layer to a build platform and exposed to a laser in the areas where it is to be melted. The platform is incrementally lowered and the process is repeated until the required component height is achieved. HORN uses aluminium (AlSi10Mg), stainless steel (1.4404), tool steel (1.2709) and titanium for 3D printing. Other materials are currently being trialled. The build volume is 300 mm (11.811") in diameter by 400 mm (15.748") in height. As HORN has all additive manufacturing processes in-house, specialists in the production area can respond directly to customer requirements. Parts are manufactured in various designs according to the intended use. HORN also supports the customer in the design and selection of suitable parameters for melting the powder. Production takes place according to customer requirements; either raw components are supplied or finish-machined components. Further advantages of HORN's in-house production is the wide range of installed machinery and metrology equipment. This saves time and has a direct influence on all production processes.

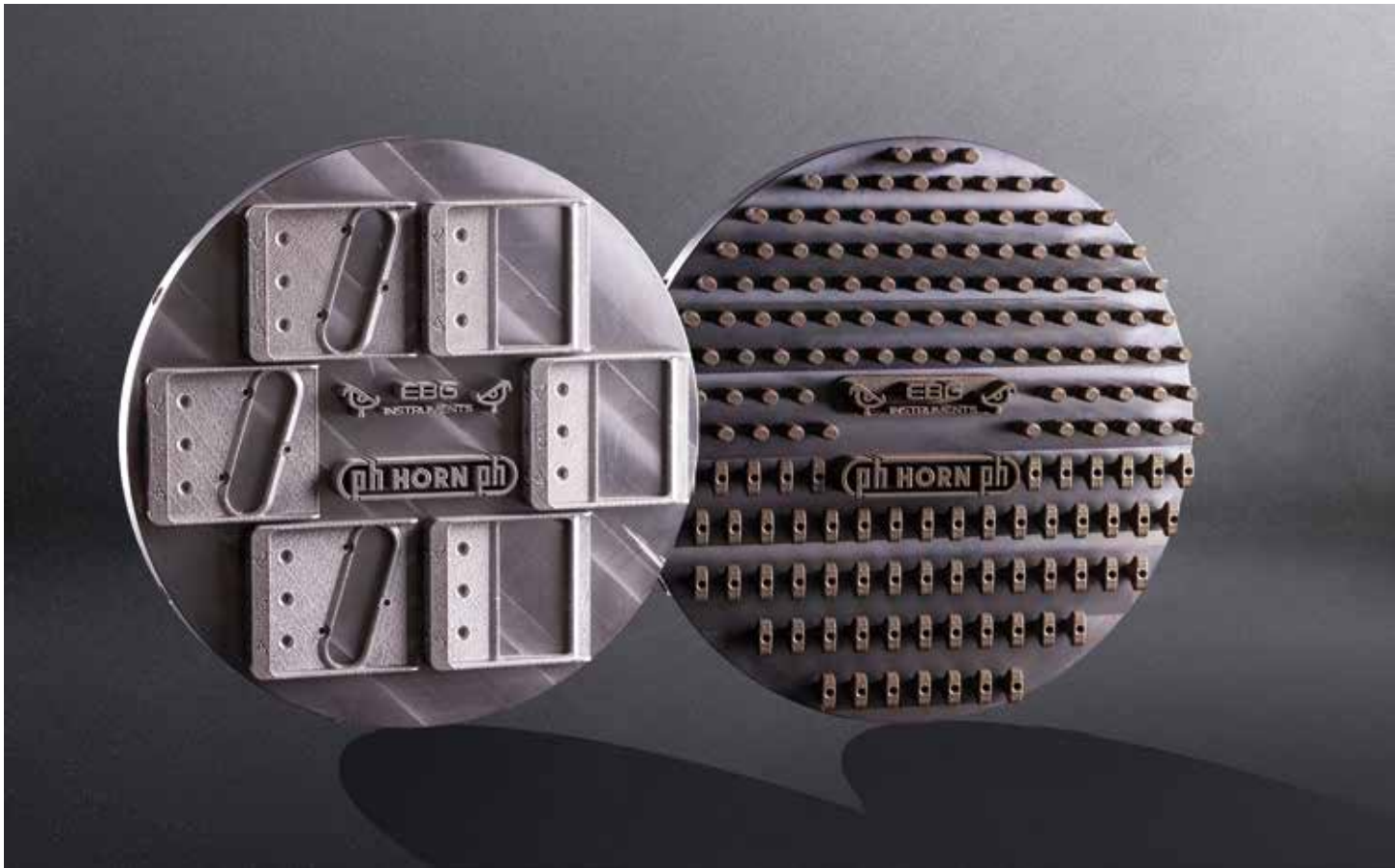
The printed guitar components are separated from the build platform by wire erosion. However, due to the high stress on the thin-walled components, they require heat treatment before eroding, as otherwise they would warp after separation. The heat treatment takes place at a temperature of 650 degrees Celsius and takes around two hours. Locher opted for glass bead blasting for the optical finish of the components. In addition to the bridge, HORN also printed other components for Locher's Telecaster.

ADDITIVE MANUFACTURING MAKES SENSE IF IT RESULTS IN A TECHNOLOGICAL ADVANTAGE.

CVD diamond milling cutter

Locher mills the guitar body from solid material. The raw part comes from a mahogany stair tread. Locher cuts it lengthways and glues the two parts

After 3D printing, the components are still firmly attached to the build platform. A wire EDM machine is used for separating the parts.



HORN uses the selective laser melting process, also known as the powder bed process.

together in mirror image. "In addition to providing greater stability, the mirror-image gluing of some woods is also an aesthetic factor in guitar making," says Locher. Special instrument glue is used, which sets nearly as hard as glass. This is very important, as soft glue joints would absorb vibrations and affect the sound of the instrument. When machining the body, Locher uses a three-axis CNC milling machine with a high-speed spindle and a four-edged diamond-tipped milling cutter from HORN.

The cutting length of the tool is around 45 mm (1.772"). This is enough to complete most milling operations on the body. Thanks to the sharpness of the cutting edges, Locher saves time during subsequent sanding. "I was extremely impressed by the milled surfaces. The flanks on the cutter are as if they were finely ground and there is no burr on the edges. This saves time when sanding the wood surfaces later," explains Locher. The tool also mills pockets without any problems by ramping into the solid. For example, Locher mills numerous hexagonal pockets as well as the electrical compartment into the body to reduce the weight. Locher later glues a 5 mm (0.197") thick mahogany top over the pockets and milled cable ducts.

Lacquer like glass

Guitar making at this high level combines numerous skills. In addition to mechanical expertise in CNC technology, the abilities of a carpenter, craftsman and lacquerer are required. Once the individual guitar components have been manufactured and the fine sanding work has been completed, the parts are painted. Locher opted for a mother-of-pearl white metallic colour for the body of the guitar. The neck made of curly maple and ebony is given only a dark brown stain and a coat of clear lacquer so that the beautiful wood grain remains visible. "Using a primer, coloured lacquer and clear lacquer, we apply nine wafer-thin layers," says Locher. Each individual layer is sanded after drying in preparation for the next layer. Painting always produces an orange peel effect. This is characterised by a slightly wavy surface appearance. The final coats of clear lacquer are therefore given a special treatment. After drying, they are sanded with increasingly fine grits and polished to a high gloss using different compounds. "After these time-consuming operations, the clear coat reflects light like a layer of glass," says Locher. The final assembly and tuning of the strings is always a special moment for him. "The first note of the finished instrument also marks the beginning of the farewell. It's difficult for me, as I've spent two to four months building it," Locher explains. He often delivers his guitars personally to their new owners throughout Europe.

Locher rates the collaboration with HORN positively: "From the initial idea of printing the components from titanium to the technical design, goal-oriented advice and implementation, the collaboration was very professional and smooth. I'm already looking forward to the next projects. Thank you very much for that."

DEUTSCHLAND, STAMMSITZ
GERMANY, HEADQUARTERS
—
Hartmetall-Werkzeugfabrik
Paul Horn GmbH
Horn-Straße 1
72072 Tübingen

Tel. +49 7071 7004-0
Fax +49 7071 72893

info@de.horn-group.com
horn-group.com