Issue 1/16

world of tools

THE CUSTOMER MAGAZINE FROM HORN

TOPICS:

- Ultra-hard cutting materials
- Gear toothing up to module 30
- Polygon milling
- Hall 10, Stuttgart Trade Fair

Dear Readers,

In this issue of world of tools we will be exploring the topic of diamond cutting materials. For much of history, diamond has been a permanent fixture in the field of machining. But while this versatile material ensures high-gloss results, it also has limitations – particularly when it comes to the material being machined. In the following pages you can find out what types of cutting materials there are, where they are used and how they have turned out in practice.

In addition, we will be discussing two special topics relating to technology. The first of these is polygon milling, which can save time by taking the place of conventional milling in this field of machining. Secondly, the machining of lead-free brass, which is becoming increasingly important in fields such as the drinking water industry due to the latest “positive list" set out by the German environmental protection agency, as well as in other EU countries.

I'm especially pleased that Hall 10 of the Stuttgart Trade Fair, which is currently under construction, is to be named “Paul Horn Halle”. There are numerous reasons for this development. Given the growth achieved by HORN, we think it's essential to extend our profile beyond Tübingen in order to appeal to potential talent in an industrialised region such as Stuttgart. Moreover, the Stuttgart Trade Fair symbolises internationalism and global trade, just like HORN.

I hope you enjoy reading our latest customer magazine.

Lothar Horn

Lothar Horn
Managing Director
Hartmetall-Werkzeugfabrik Paul Horn GmbH
Tübingen

world of tools

THE CUSTOMER MAGAZINE FROM HORN

Imprint: world of tools©, the HORN customer magazine, is published twice per year and sent to customers and interested parties. Publication date: April 2016. Printed in Germany.

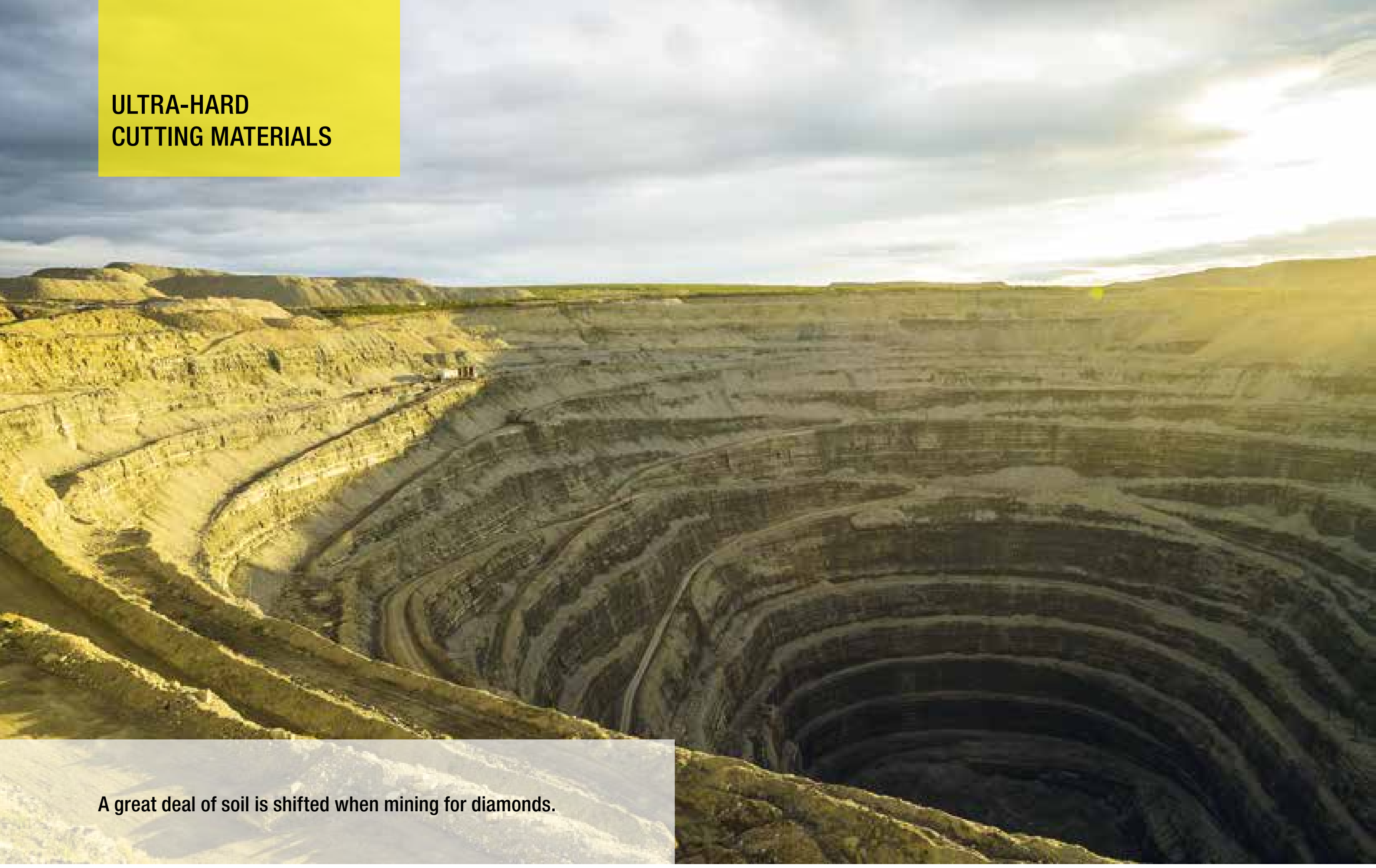
Publisher: Hartmetall-Werkzeugfabrik Paul Horn GmbH • Unter dem Holz 33-35 • 72072 Tübingen, Germany
Tel.: +49 (0) 7071 7004-0 • Fax: +49 (0) 7071 72893 • E-mail: info@phorn.de • Internet: www.phorn.de/en

Other picture credits: Nico Sauermann, Groz-Beckert, Albstadt pg. 7, Stuttgart Trade Fair pg. 22, Thomas Wagner pg. 23, fotolia, istock

Circulation: 22,000 in German, 6,500 in English and 4,000 in French

Editor/texts: Christian Thiele, Hubert Winkler, Wolfgang Dieter Schenk, Stuttgart Trade Fair

Complete production: Werbeagentur Beck GmbH & Co. KG • Alte Steige 17 • 73732 Esslingen, Germany



A great deal of soil is shifted when mining for diamonds.

THE MANY USES OF DIAMOND

From talisman and gleaming jewellery to cutting material

Diamond is one of the crystalline forms of carbon and is a naturally occurring material. The crystals, in various sizes, are transparent, colourless or imbued with numerous colour nuances by "impurities". Diamond is also the hardest naturally-occurring material. Its hardness exceeds that of corundum (aluminium oxide) by 140 times. However, the hardness of diamond varies according to the orientation of the crystal lattice. It's therefore possible to grind diamond using diamond powder. In the diamond powder used, the crystals are arranged in every orientation. This means that the hardest surfaces at any given point exert the grinding effect on the diamonds being ground.

Its high refractive index also makes it a perfect stone for jewellery. Facets which are carefully cut to precise angles produce countless interior light reflections and the unmatched brilliance which makes diamonds so valuable and splendid.

The oldest known diamond is estimated to have an age of 4.25 billion years. In this early period of Earth's history, carbon was converted into diamond crystals under high pressures and temperatures at a depth of 140 kilometres (86.992 miles). These crystals are then brought near to the surface by movements of the Earth's crust and volcanic eruptions. The oldest discoveries date back to the fourth millennium BC in India. Since at that time there was no way to cut diamonds, the hard and rare crystals were considered to be magical talismans. The use of the tough mineral in tools was first attested by Pliny the Elder in around 60 BC. One such application was the scoring of glass, which diamond greatly facilitated. Yet it was almost another two thousand years until the first cut and coveted precious stones.

Various applications

With a bulk modulus of 442 GPa, diamond is the hardest naturally occurring mineral and the material with the highest thermal conductivity – five times higher than that of silver. However, it only remains stable under normal atmospheric conditions up to 720 °C, at which point it oxidises to form carbon dioxide. Only around 12 per cent of natural diamonds can be manufactured into jewellery; the remaining diamond grit, known as "bort", as well as diamonds containing lots of impurities, are used for industrial applications: as a wear-resistant cutting material for grinding, cutting and drilling tools, as well as domestically in nail files. For comparison, a good-quality, five-carat diamond (weighing around one gram) costs around 80,000 euros, whereas one gram of bort costs a mere 40.

Growing demand

The most well-known diamond mines in the world are currently found in Africa, in Namibia and South Africa, but they are also mined in Angola, Botswana, Sierra Leone and the Congo. Russia is another country which supplies diamonds. To the east of the Ural mountains in particular, there are large diamond deposits which are mostly far from any civilisation we know and which are difficult to extract even with state-of-the-art machinery. Some speculate that the deposits total several trillion carats. Sadly, the diamonds found in Siberia, each at one or two carats at the most, are not the kind that are suitable for jewellery-making. Diamonds are also mined in the vast, untapped tropical regions of Brazil. In contrast, the Canadian mines close to the Arctic circle are now mostly exhausted. On average you need to sift through around 250 tonnes of sand, gravel or stone to obtain one carat of diamond. In total, there are approximately 700 known sites where diamonds have been discovered. In Germany, diamonds have been found in locations such as the Nördlinger Ries and near the Saidenbach Dam in Saxony.

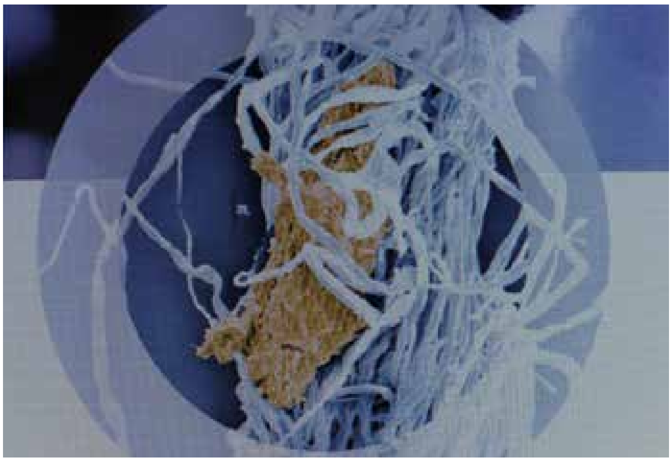
Over the last year, the rising global demand for diamonds amounted to around 75 billion euros, mainly from the US and China. Experts even predict that there will be a diamond shortage in the near future. The global production of natural diamonds is falling sharply, and is currently at a level of around 20 tonnes per year. Leaving aside the 12 per cent used for jewellery, the remaining 88 per cent only covers 20 per cent of the vastly increased industrial demand. This is why synthetic diamonds – with their properties such as toughness, crystal habit, conductivity and clarity being precisely determined – are increasingly being used to plug this gap in demand. A natural process that previously required millions of years to complete can now be achieved by technology in a matter of weeks, days and hours. These diamond cutting materials are known under the terms PCD, CVD-D or MCD, as well as type IIa diamonds for jewellery. Although natural reserves are depleting, the age of artificial diamonds is just beginning.

A natural diamond in its original shape.

CVD DIAMOND – THE CUTTING MATERIAL FOR HIGHLY ABRASIVE MATERIALS

HORN CVD-D milling cutters for machining mechanically processed cages made from cotton-fibre-reinforced phenolic resin.

The bearing specialist CW Bearing in Kürnach, Bavaria, manufactures plastic cages for high-quality special ball bearings, among other products. However, the composite material, made from a special phenolic resin and reinforced with cotton fibres, has some drawbacks when it comes to precision machining. Only the CVD thick-film diamond cutting material from the tool specialist HORN in Tübingen, Germany, can meet all the requirements in terms of dimensional accuracy, surface quality and efficiency.



In this image observed using a scanning electron microscope, hard grains of dust embedded in the cotton fibre can be seen clearly.

In 2013, the Chinese ball-bearing manufacturer CW Bearing in Kürnach, in the Bavarian district of Würzburg, constructed a new production plant. CW Bearing invested in state-of-the-art manufacturing for the production of ball bearings, spindle bearings and special bearings, as well as components used in demanding applications.

In many fields of application, the use of special cages and cage materials enhances the performance of ball bearings. In addition to those made of steel, cages made from injection-moulded plastic are used, as well as cages made from high-performance plastics. Mechanically produced cages made from cotton-fibre-reinforced phenolic resin are a key product. The working temperature of these fibre-reinforced phenolic resin cages is limited to 120 °C. This temperature must also not be exceeded during the individual machining stages.

The abrasive material

The rod material and pipes made from cotton-fibre-reinforced phenolic resin serve as semi-finished products in various different diameters. The two-metre-long (2.1783 yd.) rods are processed in the machine for each and every cage. First the outside and front face of the cage is machined. Then the internal turning is carried out in one cut with a small groove in what will later be the parting-off surface. Subsequent operations involve drilling holes into the ball-bearing slot and parting off. The finished, mechanically processed cages are then subjected to special subsequent treatment in order to improve surface quality and edge preparation.

The abrasiveness of the composite material proved problematic. New, uncoated carbide cutting edges were indeed sharp enough to separate the cotton fibres cleanly and achieve a

Parting off the ball-bearing cage with a special tool from the “Mini” range, type 18P, from HORN. The cutting material of the 1 mm (0.0394") wide tool consists of CVD thick-film diamond.

good surface quality, but their low tool life led to high costs. Experiments with coated cutting edges also failed to yield an alternative. Because of the cutting edge rounding of the coating, they were not sharp enough to cleanly separate the cotton fibres. As a result, the fibres became crushed or ripped off. Friction caused the rounding to produce excessive heat transfer (over 120 °C) and scorched or melted the phenolic resin in the cutting surface. Therefore, neither approach resulted in an efficient, technically sound solution.

Diamond cutting material as a solution

The first workable solution was introduced by the use of monocrystalline diamond (MCD) as a cutting material. The tool life and surface quality were good, but an efficient solution remained elusive. This is because something occurred which was unexpected from what was probably the toughest available cutting material: it showed signs of wear. The monocrystalline diamond is unbeatable in brilliant-finish machining and finishing. But when machining highly abrasive materials, with extreme loads subjected to the cutting edge due to wear, its cutting edges cut to the utmost precision become too good, too expensive and too valuable.

At the EMO manufacturing trade fair in 2013, attention was drawn to CW Bearings and their cutting material from HORN in Tübingen.

The initial contact was made by an e-mail to HORN. Having studied the circumstances of the issue, Andreas Schießer, the sales representative from HORN and Aribert Schroth, the product specialist for ultra-hard cutting materials, also recommended a diamond cutting edge, but one made from CVD thick-film diamond. This is because the crystal-lattice structure of natural diamond or MCD means that the maximum-hardness surface of the diamond is never on the cutting edge. This is due to the necessity of machining of the cutting edge with diamond grains of the same hardness used as the grinding agent. However, for CVD diamonds, the growth direction of the adjacent diamond crystals is aligned in such a way that the cutting edge is in exactly the same direction as the greatest hardness. CVD diamond is therefore a tougher cutting material than MCD. Diamond also offers the highest thermal conductivity of all cutting materials and the highest possible cutting edge sharpness, which has a positive effect on the cutting edge when subject to the lowest possible temperatures. The first experiments with the new cutting edges had positive results and demonstrated significantly higher tool life than the MCD cutting material – an option which is many times more expensive.

Cutting edges with CVD-D

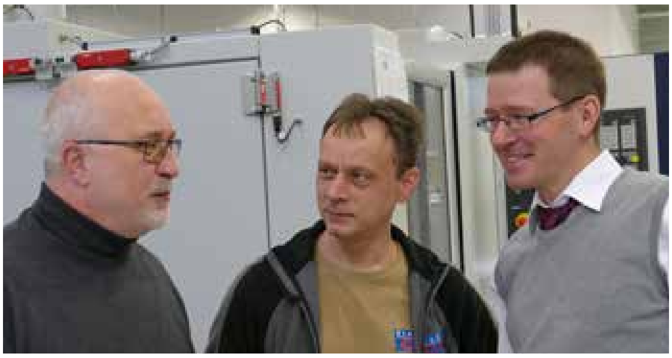
Since then, the cotton-fibre-reinforced phenolic resin cages are only machined in the key operations using cutting edges with CVD-D. The cages are chamfered and the cage interiors are turned out and pre-grooved using the Supermini type 105. The small CVD-D cutting inserts of the Supermini, which are soldered on using a special method, have a lasered geometry which is optimised for the field of application in question. The holes on the snap-action edge and the ball-bearing slot are made using drills which have been specially developed for this specific application. They feature CVD diamond on two or more cutting edges and enable drilling into solid material. Drills with a diameter ranging from 2.0 mm to 15 mm (0.0787" to 0.590551") are used. Parting off is carried out with a special tool from the 18P “Mini” range from HORN with a small soldered-on CVD-D plate with just 1 mm (0.0394") cutting width in order to conserve material. Grooving depths are possible up to 5 mm (0.1966"), and parting off can be performed from the outside towards the inside or vice-versa. The support system with asymmetrical gear teeth at the parting point is made from carbide, just like for the shafts, except the carbide here has a vibration-damping effect. The support material of the drills also consists of carbide. The small CVD-D cutting inserts are 0.3 mm, 0.5 mm or 0.8 mm (0.0118", 0.0197", 0.0315") thick, depending on the relevant field of application and the tool design which has been optimised accordingly.

Problem solved

With the experience gained from series production of the cages of a wide variety of diameters previously manufactured with these tools, the following staggering tool life properties have stood out: For cages with an interior diameter of 29 mm (1.1417"), the Supermini achieves a reliable tool life of 10,000 parts as a boring tool. The drill with 8 mm (0.3150") diameter achieves 80,000 drilling holes at 4 mm (0.1575") drilling depth. This demonstrates a significantly higher tool life compared with tools fitted with an MCD cutting edge. The same also applies for parting off with type 18P. Bernd Schubert, bearing specialist at CW Bearing is particularly happy with the equipment: “We have solved our problems and found the most efficient method. The savings we achieved were thanks to lower tool costs and higher production capacity as a result of fewer tool changes. What's more, we have also managed to significantly increase quality in a reliable way.”

The hidden secret of the cotton fibre

But why does phenolic resin combined with cotton fibre even manage to cause wear to diamond cutting edges? Common consensus would tell us that neither phenolic resin nor cotton is abrasive enough to cause wear to cutting materials such as carbide or diamond on the cutting edge. We also don't take into account that a chemical attack occurs on the cutting edge in the temperature spectrum of under 120 °C on the cutting edge. This is not down to the phenolic resin, but rather the soft cotton used as cladding, which hides tiny silicate crystals within its fibre structure. Cotton is cultivated mostly in very dry regions. The wind sprays the cotton bolls with extremely fine mineral dust particles, which are then trapped in the fibre structure while they are being shaped. The textile industry has been aware of this wear caused by cotton fibres for quite some time. The needles of knitting machines and thread guides – which rub against the cotton and sometimes are even sawn right through by them – are particularly affected. These silicate inclusions can be seen clearly in images of cotton taken using an electron microscope.



Plant manager Ferdinand Wiedmann and the bearing specialist Bernd Schubert at CW Bearing with the HORN sales representative Andreas Schießer (from left).

Mirror system from the vacuum chamber. The geometrically precise, brilliant-finish surfaces of the flat and concave mirrors enable numerous reflections of a terahertz beam introduced just once. Made visible by a reflected green laser beam and evaporating cooling medium.

BRILLIANT-FINISH MACHINING

Mirror finish and starlight

In the specialised facility of the laboratory astrophysics department at the University of Kassel, the matter from which our stars are born is created in a small vacuum chamber. The scientists are creating materials which otherwise only exist in outer space in order to learn more about how stars both grow and decay. Sophisticated laser technology and high-precision mirror systems aid the researchers in investigating their ideas and theories. The geometrically precise mirror systems made from aluminium and offering a high reflection coefficient are manufactured using a ballnose end mill from HORN in Tübingen, and are fitted with a cutting edge made from monocrystalline diamond (MCD).

The small vacuum chamber at Kassel's Institute of Physics contains the secret of the cosmos. Using this chamber, Prof. Dr Thomas Giesen and his team of researchers are recreating the conditions as they are during the various phases of star formation.

Prof. Giesen explains the basic principle: “Under a vacuum and at temperatures of minus 250 °C, which is just above absolute zero, scientists can create molecules in the metallic chamber under certain conditions which only otherwise exist in outer space. The highly energetic processes during the so-called 'embryonic' phase of stars are recreated by means of intense laser pulses. The laser pulses are fired onto a material such as high-purity graphite. If it was continuously in operation, the power usage for the laser pulse would equal that of the entire city of Kassel. Luckily, we researchers only need the high energy for a billionth of a second. This is enough so that the graphite, which consists of elemental carbon, is decomposed into its atomic constituents.”

From 10,000 °C to minus 250 °C in milliseconds

“We then have to cool down from the 10,000 °C present in this extremely high-energy moment to minus 250 °C in a split second. This is achieved,” says Giesen, “by introducing a nozzle-jet of helium gas into the vacuum chamber at supersonic speeds. Because the gas expands so abruptly in the airless chamber, the temperature drops at lightning speed. In this environment, individual atoms can be recomposed with one another just like in outer space. Completely different compounds than those under terrestrial conditions are formed here. If we take carbon, for example, 100 different types of molecule are created in this process.”

In order to analyse these molecules, the scientists enlist the help of terahertz spectroscopy technology. The terahertz spectral range is between far infrared and microwave, and includes frequencies from 300 GHz to 10 THz, i.e. wavelengths between 1 mm (0.0394") and 30 μm (0.0012").

Beams of terahertz-level frequency are sent through a gas under examination and captured again by a sensor. Each gas

Led by Prof. Dr Giesen, the group of young researchers investigates the matter stars are made from.

has a different absorption coefficient and absorption pattern. The individual gases therefore differ in terms of their absorbed frequency spectra. In the laboratory, terahertz beams of various frequencies are passed through the gas under analysis, thereby producing a unique “fingerprint” of the gas being investigated.

Jens Deichmüller, Technical Advice at HORN, Ingo Schulz, head of department at university workshops and Detlef Brill, machine operator (from left): 300 mm (11.811") Mirror and CVD-D diamond cutting edges as the next objective.

Unsuitable milling cutters

To achieve this, a terahertz beam is passed through an opening in a flat mirror in the vacuum chamber, which then is reflected by a concave mirror back onto the flat mirror. The more often the beam is reflected back and forth in the mirror system, and therefore the more often the beam passes through the gas, the clearer the signals become. Finally, a detector behind the opening on the flat mirror captures the beam. In order to see the invisible terahertz beam in the mirror system, a visible green laser beam is superimposed.

All of the special terahertz optics used previously had weaknesses. Only metallic mirrors brought the researchers closer to their goal. Yet prior experiments with milling and polishing did not produce the surface quality required. The milling grooves were too deep and additional geometric imperfections were introduced by polishing. As a result, there were not enough suitable reflection passes in the mirror system.

On the right path with MCD milling cutters

In an article featured in “world of tools”, the customer magazine by the tool specialist HORN, Ingo Schulz, head of the department at the precision-engineering workshops at the university, hit on the topic of mirror milling with MCD tools. The initial tests already showed that we were on the right path with these MCD milling cutters. In order to improve results, the area resolution in the CAM program OPEN MIND hyperMILL was refined to 0.0005 mm (0.000001969"). The Heidenhain control of the Hermle C20U was able to process this resolution with no problem. A concave mirror with a diameter of 100 mm (3.9370") and a mirror radius also of 100 mm (3.9370") is milled from the aluminium material AlMgSi05 in multiple stages:

- **The raw part is rough-machined with an 8 mm (0.3150) carbide roughing mill. (0.25 mm (0.0098") allowance, 17 minutes machining time)**
- **Profile rough milling of the surface with 10 mm (0.3937") carbide ballnose end mill. (30° setting of the swivel table, 0.5 mm (0.0197") line spacing, 0.1 mm (0.0039") allowance, 7 minutes machining time)**
- **Profile first-finishing of the surface with 10 mm (0.3937") ballnose end mill. (30°, 0.1 mm (0.0039") line spacing, 0.03 mm (0.0118") allowance, 35 minutes machining time)**

Resolution of 5.1 million items of data

The fourth stage is to brilliant-finish mill the mirror. To this end, a ballnose end mill of type 117 from HORN is used with a vibration-damping, carbide round shank and an S117 cutting insert for a diameter of 10 mm with an MCD cutting edge and aluminium geometry. Milling is then carried out with the following parameters: v_c = 400 m (15.748")/min., f_z = 0.03 mm (0.0012"), a_p = 0.03 mm (0.0118") and a_e = 0.03 mm (0.0012"),. During this process, an NC program size of 123 MB is executed, equating to 5.1 million items of data and a machining time of 11.5 hours – for one mirror measuring 100 mm (3.9370") in diameter.

Unlike during the preliminary stages, in which milling is performed with cooling lubricant due to the potential for built-up edges being formed, cooling lubricant is not necessary when milling with MCD cutting edges because the diamond materials do not demonstrate an adhesive tendency. This is also why Ingo Schulz will switch to using diamond for the preliminary stages in the future – CVD-D diamond, to be precise. It is also hoped that, during the essential profile first-finishing in particular, the geometric accuracy and surface quality is improved even further prior to brilliant-finish machining thanks to the easy cutting and low cutting pressure.

Even more precise fingerprints using 300 mm (11.811") mirrors

In the final stage, the mirror is polished very gently and without much pressure being applied. Using MCD cutting edges from HORN, the flat mirrors are also produced in Kassel, with 300 mm (11.811") concave-mirror production planned for the future, which would then require over 20 million items of data. In order to facilitate this, however, the computer systems must first be upgraded.

Mirror-finish milling of the concave mirror surface with vibration-damping carbide shaft from the type 117 range and 10 mm cutting insert type S117 with monocrystalline diamond cutting edge.

With this precise, brilliant-finish mirror geometry, 20 to 30 reflection passes can now be achieved reliably in the mirror system, thereby providing an even more accurate basis for analysis. Each type of molecule leaves behind a characteristic image. "When we talk about a molecular fingerprint of the molecule, that's like an unmistakeable DNA signature", explains Prof. Giesen. In the next stage, the scientists carry out tests to see whether the fingerprint of the molecule also exists in the light emitted from outer space towards the Earth. The signals are compared using the highly sensitive IRAM radio telescope in the Spanish Sierra Nevada, which is 30 m (328.084 yd.) in diameter. If the fingerprints observed in Kassel can also be found from these signals, this is proof that these molecules also exist in the far reaches of outer space. These are tiny puzzle pieces, but ones which can be used to construct a vast overall picture. The scientists at the University of Kassel are working on completing this picture in cooperation with international research organisations from the US, France and Japan.

Eurosealings offers 25 different types of PTFE as a sealing material for a wide variety of sealing rings from 1.2 mm up to 620 mm (0.0472" up to 24.4094") in diameter.

PCD SAVES 80 PER CENT IN MACHINING COSTS

The company Eurosealings in Schelle close to Antwerp, Belgium, specialises in making highly resilient seals made from Hastelloy, Inconel, other highly resistant metal alloys and various PTFE types. They are suitable for pressures up to 6,800 bar and temperatures ranging from -269 °C to 980 °C, while also resisting almost all aggressive media. It comes at no surprise, then, that the company also uses high-performance tools in their production processes, including ones from HORN in Tübingen.

A small selection of the PCD die plates used today. With the support of CNC technology, these will allow several contour variations to be machined. Each one removes the need for numerous, specialised carbide die plates.

Founded in 1992 and employing 15 highly qualified staff, Eurosealings manufactures high-quality and highly resilient seals for use in almost all industrial sectors, such as chemical and food technology, the fittings industry, turbine and engine manufacturing, hydraulic and pneumatic applications, machine tools, aviation and aerospace, and many more. The batch sizes vary from just one item to thousands of items. The diameters of the high-performance seals, made from nickel-based alloys or stainless steel, as an O-ring or C-ring, coated or uncoated, range from 6.12 mm to 2,500 mm (0.2409" to 98.4252").

Variations increased almost 40-fold

Eurosealings produces PTFE seals for static or dynamic sealing in over 25 compounds and diameters starting from 1.2 mm on the inside up to 620 mm (24.4094") on the outside and up to 2,000 mm (78.7401") as a special size. The compounds consist of the PTFE basic material filled with glass or carbon fibres, in combination with graphite, electrographite or Ekonol, an inorganic filler. Numerous different mixture ratios fulfil the specialised and specific requirements of a wide variety of customers. The PTFE seals are always designed with a C-form groove with various seal geometries.

Axial grooving with HORN type 114 with PCD cutting edge in pure, off-the-shelf PTFE. Optimum surface quality and no burr formation.

Cutting insert for manufacturing the entire interior contour of a PTFE seal using a PCD cutting edge. Whereas previously the interior contour had to be mapped out using several special carbide die plates, today just one PCD die plate is required.

Small and medium-sized sealing rings are machined from the pipe. Shown in image: machining an interior contour using the HORN type 114 with PCD cutting edge.

Stabilising hairsprings or V-springs made from the materials Hastelloy, Inconel or Elgiloy are used to support the C-form, which is opened either axially or radially, depending on the specific requirements. These PTFE seals are temperature-resistant up to 265 °C, at peak up to 300 °C, at pressures up to 3,500 bar for static applications and 550 bar for dynamic applications. The range of variation is currently at over 10,000 available types of seal.

At the frontier of efficiency with carbide cutting edges

In the past, the number of seal geometries and variants available at Eurosealings was limited. For every interior and exterior geometry of each seal variant, various special carbide steel sections were required for machining. These steel sections also quickly wore out due to the abrasive substances contained by the seals and required continual re-grinding. In addition, the precision geometry was altered with each grinding process, meaning that the machine operator was under high pressure in making readjustments on the CNC and dimensional checking, which raised some issues over efficiency in terms of productivity and reliability. This was not least because of continual tool breakage on the precision supports and structures of the moulding tools. The high rate of wear and continual regrinding led to excessive tool stock and costs in order to stockpile a sufficient number of tools for machining.

The reasons why the cutting edges wore away so readily are manifold – most of which were combined with others: glass and carbon fibres, graphite, k-carbon and E-carbon. The most prominent source of wear in this regard seemed to be the structure of the E-carbon mixed into the PTFE microstructure at high concentrations.

PCD – the instant solution

Consistent implementation of modern CNC and CAD/CAM technologies spurred on a sea change which was introduced in the context of a new tool strategy. Tests of the cutting material PCD as an alternative to carbide had already been carried out for some time at Eurosealings, but the breakthrough in efficiency was still yet to be found. Having taken a keen interest in information on the high-performance cutting materials from HORN, Eurosealings enlisted the advice of Kees van Bers, the HORN sales representative responsible for the Flemish regions of Belgium. Kees van Bers already had a wealth of experience with the machining of various PTFE-based materials from other applications, so he immediately recommended the ideal and universal PCD solution for all PTFE materials used at Eurosealings. The special cutting contours required were ground at the

HORN production facility in Tübingen, and were delivered and installed in no time. Even the optimisation phase, which would otherwise always be performed, was unnecessary here and was skipped entirely. Only the material UHMW-PE (ultra-high-molecular-weight polyethylene) still caused problems due to burr formation. But with the help of technologists from back in Tübingen, Kees van Bers was quickly able to find a solution to this: the same PCD substrate, yet with enhanced sharpness of the cutting edge thanks to special precision grinding.

(from left) Jo Maes, responsible for PTFE manufacturing, Kees van Bers from HORN and Geert van Kelst from Eurosealings are fully satisfied with the 80 per cent cost reduction thanks to the PCD cutting edges.

A new role in a competitive environment

"Today," according to Geert van Kelst, sales and quality manager at Eurosealings, "we can use the new freedoms and possibilities we have gained – by expanding our CNC capabilities in conjunction with the PCD tools – to great advantage in this competitive environment. As a small and flexible company which is open to providing specialised solutions, we can deliver what others – with large standard product lines – are unable to at this level of flexibility. For example, we manage to deliver specialised solutions to our customers in as little as two days. News of this feat travelled fast, and we were introduced to new customers as a result. In order to continue along this trend, we are currently investing in systems for manufacturing our own varieties of PTFE, such as mixers, a large enough press and sinter technology."

PCD saves 80 per cent in machining costs

When evaluating the use of PCD to machine various PTFE varieties from an efficiency vantage point, Geert van Kelst is more than happy to sing praises: "When it comes to machining these different varieties, we have seen a six to ten-fold increase in tool life. What's more, we have kept non-productive times for tool changing, readjustments, inspection and the associated administrative effort down to a minimum. Rejection and cutting parts for inspection purposes are now a thing of the past. Surface quality is now consistently outstanding and shows no signs of burr formation. There's now no need at all for the manual deburring we were doing before. Tool breakage is also no longer a factor in terms of costs. Because of the high cutting speeds, deposits always used to build up as well, which had a massive negative impact on surface quality. This made carbide cutting edges unusable and they therefore had to be reground prematurely. Today, with the PCD cutting edges, the high diamond content on the surface of the cutting edge and the excellent heat dissipation properties of the diamond cutting materials, deposits are prevented from building up. All in all, the gains in terms of reliability have been enormous. If we took into account all of the measures that were achieved with the use of PCD cutting materials, we are now saving around 80 per cent in machining costs compared with before." After a short pause, he continues: "You know, the great advantage of having HORN as a partner is that they're either thinking on the same level as you or they're already way ahead! It is always a positive experience solving problems together with HORN. Kees van Bers comes to visit our facility about every six weeks. Any new experiences he has gained are delivered to us directly and implemented on the machines, so that we're always up to date."

Whereas previously Eurosealings needed 275 carbide steel sections in order to produce all seal geometries and variations, today they can enjoy enormous cost reductions and efficiency gains thanks to the use of fewer universal steel sections with PCD cutting edges. Now, with the universal steel sections, over 1000 different profiles can be manufactured instead of just standard profiles like beforehand. The adoption of universal steel sections with PCD cutting edges also conferred a key competitive advantage as a result.

AN OVERVIEW OF DIAMOND TOOLS

Polycrystalline diamond (PCD)

PCD is a synthetic substrate formed from diamond particles in a metallic binding chamfer. It is produced by high-pressure, high-temperature synthesis or by high-pressure liquid phase sintering. With around 90 per cent diamond content and diamond grains between 3 and 30 µm (0.000118" and 0.00118"), the tough, wear-resistant PCD cutting edges have a very high tool life when used for machining non-ferrous materials. The intense sharpness of the cutting edge – at around 3 µm (0.000118") at the smallest – is achieved by grinding, electrical discharge machining or precision lasers. The metallic binding chamfer imbues a certain degree of toughness which is advantageous in some applications. The main application areas are aluminium alloys containing more than 4 per cent silicon, carbide green compacts, titanium alloys and CFRP and GFR composite materials.

Cutting insert and milling cutter with PCD.

CVD thick-film diamond

Synthetic CVD thick-film diamond is created by chemically coating a carrier substance from the gas phase. CVD diamond is almost pure diamond, at 99.9 per cent. When used for a cutting material, it is created by layering coatings between 0.2 (0.00787") and 2 mm (0.0787") onto tool holders. For CVD diamond, which consists of adjacent, rod-shaped diamond crystals, the cutting edge is in the exact same direction as the greatest hardness. CVD diamond is therefore a tougher cutting material than both PCD and natural diamond. In addition, CVD diamond, like natural and MCD diamond, has the highest thermal conductivity of all cutting materials and, thanks to a precision-lasered cutting edge at 2 µm (0.00007874"), has the second highest possible cutting edge sharpness after MCD. The sharp cutting edges afford particular advantages when used for machining CFRP and GFR composite materials, carbide green compacts and even ready-sintered carbide, as well as aluminium wrought alloys with high tool life.

Cutting insert and milling cutter with CVD-D.

Monocrystalline diamond (MCD)

Monocrystalline diamond consists of pure carbon in the form of natural diamond or has been synthesised in a high-pressure process with 60,000 bars of pressure and temperatures of over 1,500 °C. Cutting edges, ground with the highest in precision in a similar way to that of precious stones, are used for brilliant-finish machining of non-ferrous metals such as gold, silver, brass and copper, but also of plastics and aluminium alloys containing less than 4 per cent silicon. MCD is the only cutting material which enables brilliant-finish machining with geometrically defined cutting edges. Its advantages comprise the intense hardness, microstructure-free texture, high thermal conductivity and low adhesive tendency.

Cutting insert and milling cutter with MCD.

New aluminium grooving geometry

Snarl chips are not uncommon when turning and grooving aluminium materials. They are obstructive, causing damage to sensitive, finished surfaces and also compromising process reliability.

So to stop these from appearing, HORN has developed a new geometry especially for grooving and parting off aluminium for the S100 and S224 grooving systems. This involves a precision-ground, sharp, positive cutting edge, grooving widths of 2 and 3 mm (0.07874" and 0.1181") and grooving depths of up to 18 mm (0.7087"). The polished chip-shape geometry serves to counteract the formation of built-up edges whilst only creating small, spiral chips, thereby ensuring excellent chip control and a high level of process reliability. The adapted chip tapering prevents flank damage while grooving to establish a premium level of surface quality. The WA geometry ensures an accurate and easy cutting process when grooving, parting off and finish-grooving. The optimum feed rate (f) is between 0.07 (0.0276") and 0.25 mm (0.0098")/rev.

In addition to the uncoated design in the K10 model, HORN also offers an alternative in the smooth DD26 coating for machining aluminium with a higher silicon content. This, too, ensures that there is virtually no formation of built-up edges.

Tool holders with internal cooling – particularly via the clamping finger – are recommended for optimal machining conditions. The internal cooling therefore acts directly within the cutting zone, thus ensuring the best cutting conditions. The cutting inserts are suitable for use in both right-hand and left-hand tool holders. H100 and NK100 tool holders / cartridges are assigned to S100 cutting inserts. The B224, BK224 and H224 tool holders / cartridges help to hold the S224 cutting inserts in place. Various coolant outlet options are available: via fan nozzles on the side of the cutting insert, via a clamping finger, or via a combination of the clamping finger and support.

The new geometry with precision-ground, sharp, positive cutting edge.

Snarl chips are not uncommon when turning and grooving aluminium materials. This is counteracted with the new geometry.

Circular 932 cutting insert for milling

Nine cutting edges for higher feed rates.

As an expansion to the range of triple and six-edged milling inserts in the 332 and 632 models, HORN has developed an even more powerful version in the 932, which comes complete with nine cutting edges and 50 per cent more machining capacity.

This offers milling widths of between 2 and 4 mm (0.0787" and 1.575"), a groove depth of 8.3 mm (0.3268") and a cutting edge diameter of 31.7 mm (1.2480"). And when it comes to the cutting insert holder, M332 milling cutter shank and AS45 carbide grade, HORN has certainly stuck to its tried-and-tested principles. The nine cutting edges facilitate significantly higher feed rates at the same cutting speed whilst also increasing productivity by around half and ensuring long tool lives and reliability.

DAH37 high feed rate indexable insert

The carbide grades developed by HORN specifically for high feed rate milling boast an incredibly high tool life thanks to their high levels of toughness and wear-resistance. When rough moulding the tooth profile of a large-module tooth segment, a DAHM.37 milling cutter, with a diameter of 40 mm and five DAH37 cutting edges in a material 42CrMo4, achieves a chip volume (Q) of 720 mm³/min.

These newly developed DAH37 cutting inserts are available in two geometries: one neutral and now a new positive one. The SA4B and SC6A-grade neutral geometries and the SA4B-grade positive geometry machine every steel grade from unalloyed to high-alloy, martensitic and austenitic stainless steels, non-ferrous and casting grades with a cutting depth of up to 1.2 mm (0.0472").

The triple-edged indexable inserts, with dimensions a = 7.9 mm (0.3110"), H = 3.18 mm (0.1252") and a corner radius of 0.8 mm (0.0315") are fixed in a precision holder with a clamping bolt. DAH37 indexable inserts fit in milling heads of the DAHM system with 20/25/32 and 40 mm (0.7874"/0.9843"/1.2598" and 1.5748") cutting edge diameter, screw-in milling cutters of the DAHM system with MD tool holder also with 20/25/32 and 40 mm (0.7874"/0.9843"/1.2598" and 1.5748") cutting edge diameter. Both types of milling cutter are equipped with 2 to 5 DAH37 indexable inserts depending on the diameter. The DAHM cutter heads as arbour milling cutters with cutting edge diameters of 40/50/63 and 80 mm (1.5748"/1.9685"/2.4803" and 3.1496") hold 5 to 8 indexable inserts.

New geometries in combination with high-performance grades of carbide.

HORN has developed numerous standard tools used for machining all gear-wheel geometries.

GEAR TOOTHING UP TO MODULE 30

HORN expands its product portfolio upwards

The current trend in the gear wheel industry is for smaller batch sizes and greater variety, and HORN supports this with a whole host of high-performance, cost-effective gear-milling solutions on universal machine tools. HORN has the right solution for every gear-tooth geometry between module 0.5 and module 30. Even in individual parts, prototypes and small and medium-sized series, our solutions are the most economical way of generating all kinds of top-quality gear-tooth geometries right up to module 30 using standard tools.

The gear-milling range comprises:

- **Milling spur gears with straight, helical or double-helical gearing**
- **Milling shaft/hub connections**
- **Broaching external and internal gear teeth**
- **Milling worm shafts**
- **Milling bevel gears and pinions**
- **Milling customer-specific gear-tooth profiles**

The range of milling systems is designed to accommodate every application up to module 6 depending on the module size (DIN 3972, reference profile 1): For modules 0.5 to 3, spur-cut, 6-edged inserts for milling by circular interpolation (types 606 to 636) mill tooth profiles in a single pass. The cutting inserts are standardised for the most common gear-tooth sizes. Different cutting inserts are used depending on the width and depth of the profile.

Module-specific solutions

The 613 design, for example, offers the following advantages for modules 1 and 1.5: at a cutting edge diameter of only 21.7 mm, (0.8543") six teeth ensure short machining times for machining gear teeth on shafts even if there is limited space available. The carbide grade AS45 opens up a wide range of applications, with exceptional tool lives.

613 gear milling cutters of modules 0.5 to 3, screwed into place on the face side.

Type M279 milling systems with two-edged cutting inserts screwed onto the axes are the ideal solutions for machining modules 3 to 4. Single-row or double-row milling cutters are used depending on the profile type. The main bodies are made to correspond to customer requirements. For modules 2.5 to 6, type M121 form profile milling cutters with freely profilable single-edged indexable insert slotting cutters can also be used as an alternative. With a milling body to match customer requirements, the tooth profile is produced in a single pass.

From modules 4 to 30, HORN offers gear-milling solutions for prototypes and small and medium-sized series on universal machining centres using standard tools, such as end mills, ballnose end mills, toroidal milling cutters, side milling cutters, cup wheel milling cutters and conical milling cutters from HORN's standard range. Software modules such as “gearMILL” from DMG MORI provides the basis for this machining.

Advantages of standard tools

Supported by the software, standard tools produce every tooth profile geometry: spur gears with straight, helical or double-helical gearing; worm wheels; various bevel gears and pinions such as the “Klingelnberg” Cyclo-Palloid gears or the various “Gleason” derivatives. DGM, DSDS and DAH37-type high feed rate milling cutters or side milling cutters carry out the rough milling. Solid carbide end, torus and radius milling cutters of the DSM system machine tooth form flanks and base profiles. DGFF-type milling cutters deburr and mill. Exchangeable head milling cutters of the DG system, specifically DGVZ milling cutters, are also used. Following hardening, standard milling cutters with CBN cutting edges or made of special carbide grades carry out the final machining. All of these are cost-effective standard milling cutters with short delivery times.

Gear toothing on universal machining centres

As a result of all this, highly complex gear wheels can be produced on universal, five-axis turning and milling centres. The benefits in terms of time and money when using these compared to production on expensive gear tooth machines is enormous, as in single-part production, for the prototype sector or small and medium-sized series, the respective raw part geometries and then the gear wheels – and then completely different parts – can be manufactured in the same clamp.

Gear broaching

Gear tooth broaching with standard tools systems on universal turning and milling centres provides an equally cost-efficient alternative in the production of straight or helical external and internal gear teeth with different tooth profiles and module sizes in small and medium-sized batches. Our universal turning and milling centres are an outstanding substitute for milling interior gear teeth, in particular, without needing expensive internal broaches on special broaching machines. What's more, flexibly using the existing machine base also opens up a whole host of prospects to help you save time and money. Being able to machine the workpiece from raw part to toothed finished part in the same clamp and on the same machine also helps to achieve a higher level of precision.

Thanks to its decades of experience, HORN is also able to provide a wealth of new solutions in the gear-tooth broaching sector as well as tried-and-tested tool systems such as Supermini types 105 and 110, as well as the S117 type. The preliminary and final broaching stages, which use just one cutting insert, cut down cycle times significantly.

The S117 tool is in 12 o'clock position when broaching internal gear teeth.

A glimpse into the rooms of the training programme and the HORN Academy – the spatial epicentre of Patrick Wachendorfer's activities.

TRAINING AND ADVANCED TRAINING AT HORN

An important field which paves the way towards the future

Patrick Wachendorfer, training manager and academy coordinator, at Paul Horn GmbH since 1989. He has been the training manager since 1996, and was also appointed to academy coordinator in 2011.

Mr Wachendorfer, what kind of career paths do you train people for?

We currently train for the roles of industrial mechanic, industrial maintenance mechanic, electrician for operating technology, and industrial clerk. Starting from Autumn 2017, the roles of warehouse operator and warehouse logistics specialist will also be added. There are also academic training possibilities.

How is this training course structured?

In cooperation with the DHBW Stuttgart, Campus Horb, we are offering a mechanical engineering course in the field of production technology, specialising in cutting-tool technology. In this highly practical academic course, lesson blocks spent in the university are complementary with those on the factory floor. In addition, the study plan is followed alongside challenging project work. After three years, the apprentices are awarded a Bachelor of Engineering.

What sort of advanced training is there in the HORN Academy programme?

Each year we publish an internal and external advanced training catalogue. The internal advanced training catalogue can be divided into "professional" and "personal" sections. One special advanced training opportunity is the industrial specialist in cutting tool technology, which concludes with an IHK examination. During this course, internal and external instructors impart their expert knowledge on the manufacturing of precision tools over 240 hours of both theoretical and practical lessons. The external advanced training catalogue offers customers up to seven seminars which are free of charge. These seminars will be on a variety of topics relating to the field of machining.

How much can customers benefit from what the Academy is offering?

The benefits for customers are twofold. One the one hand, they benefit when they take part in the courses personally and return to their companies with added value. Incidentally, the courses are not product-specific, but focused on a certain topic. So this is not just a promotional event – the technical context with reference to practical application is the central focus. On the other hand, customers can also benefit from the expertise of employees at HORN. This allows them to accelerate their processes while minimising errors.

How significant are the training and advanced training opportunities at HORN?

The training and advanced training opportunities are of key importance in the company and are supported and maintained on all levels of the hierarchy, including management.

Tübingen/Stuttgart is a prominent economic hub. How does HORN approach what it calls the "campaign for the brightest minds"?

HORN is offering not "just" a good job, excellent training and advanced training opportunities, and a state-of-the-art work environment. HORN is offering a holistic package where you're treated as a person, not a number; where there are challenges, recognition and much more.

Will the training be changed in the future by the increasingly prevalent subject of "Industry 4.0"?

The subject of Industry 4.0 is a current topic – even for those of us working in training. When you see how much digitalisation has revolutionised everyday life over recent years, it is obvious that this issue is affecting working life in industrial fields. I cannot yet tell you how exactly the training might be changed, but change itself is for certain and we are looking forward to seeing how it progresses. Having said that, I'm confident that the present training programme is sustainable for the future. For this reason, I expect that there will be additional development of the existing system.

What is your personal desire and expectation when it comes to training and advanced training for the future?

Each day we take one or more steps towards the future. This is only possible when we cooperate. That's why I still want to see motivated and engaged young people, but also experienced people as well, with whom we can move forward and progress.

Learn more:
www.horn-akademie.de

The first sod was cut for Hall 10 by the Stuttgart Trade Fair on 14 January 2016. Text on the placards: "We are building the new Hall 10 for you – our customers!"

CONSTRUCTION OF PAUL HORN HALL BEGINS

The Stuttgart Trade Fair is expanding its site

Partners, trade-fair managers and builders cut the first proverbial sod for the expansion of the Stuttgart Trade Fair on its own land

The excavator shovel powerfully digs into the soil on the construction site for the new Hall 10 of the Stuttgart Trade Fair. What must be daily routine work for the staff of Gfrörer Schotterwerk from the town of Horb is a welcome break from desk work for the prominent "construction helpers" at the photo day – and they clearly enjoyed themselves! They certainly had cause to celebrate – this work will complete the trade-fair ensemble with the addition of the last missing hall and an upgraded west entrance. Peter Hofelich, State Secretary of the Ministry of Finance and Economics in the German state of Baden-Württemberg and Chairman of the Supervisory Board at Landesmesse Stuttgart GmbH, puts it in a nutshell: "The work begun with this foundation stone ceremony will make the architecture of the Stuttgart Trade Fair even more attractive and provide the state's economy with an even bigger platform to showcase its products and innovations."

It has only been eight years since the Stuttgart Trade Fair moved to its new location next to Stuttgart Airport. During this time, the company has generated healthy profits and can now fund development of the new hall, along with the new west entrance, with its own financial resources. "It is incredible to witness the progress the Stuttgart Trade Fair has made over the past eight years. I am most impressed by the speed at which this has happened", said a visibly excited Michael Föll, First Mayor of the state capital Stuttgart and also Deputy Chairman of the Supervisory Board at Landesmesse Stuttgart GmbH.

Gross area of 120,000 square metres

With regard to the constantly growing demand for exhibition spaces, Ulrich Kromer von Baerle – Managing Director and Management Representative at the Stuttgart Trade Fair – says: "I am delighted that the new Paul Horn Hall, our Hall 10, is finally taking shape. Once it is ready in 2018, we will be able to provide our exhibitors with 15 per cent more space. For the Stuttgart Trade Fair, this means another quantum leap forwards with positive effects on our turnover."

With the new construction, the Stuttgart Trade Fair is extending its gross overall exhibition space from 105,200 to 120,000 square metres. This is taking place on land already owned by the trade fair, on a construction site which was previously used as a car park and has been designated for this extension from the beginning. “The leasing for Hall 10 is already in full swing. We are even looking at requests as far ahead as the year 2024”, adds Managing Director Roland Bleinroth, who is also pleased that “with the new overall space, we will move up to eighth place in the rankings for trade-fair organisations in Germany.”

Paul Horn Hall

The latest development from the Stuttgart Trade Fair already has a name: Paul Horn Hall. The precision tool manufacturer from Tübingen, a regular visitor to the AMB exhibition and the Moulding Expo, has secured the rights to name the hall.

The works are currently on schedule. The projects tendered were awarded to three companies from around the state. Demolition works went to Oettinger GmbH from the town of Malsch near Karlsruhe, excavation has been awarded to Gfrörer Schotterwerk from Horb and the skeleton construction work will be carried out by MOSER GmbH & Co. KG from Freiburg.

Lothar Horn (second from right) laying the ceremonial foundation stone for Paul Horn Hall at the New Year reception of the Stuttgart Trade Fair.

Completion of Paul Horn Hall is scheduled for the end of 2017. Normal service will continue at the trade fair until then, with only minor changes as a result of the construction works. The former west entrance had to go. It has been replaced by a temporary entrance, erected directly adjacent to its former location, which will serve as an interim entrance to the trade-fair grounds.

This interim entrance affords visitors all of the amenities provided by the former entrance. A small area of Hall 9 also had to be cordoned off for the entrance to the trade-fair grounds. Despite these changes, it will still be possible to visit every hall at the trade fair without any problems. The bus stops and taxi ranks will remain at the west entrance.

The foundation stone of the new Paul Horn Hall (Hall 10) at the Stuttgart Trade Fair.

Polygonal milling cutter for grooving or longitudinal turning.

POLYGON MILLING

Cost-effective alternatives to milling

Polygon milling is the cost-effective alternative to milling when it comes to making narrow and flat surfaces on the circumference of round workpieces in series production. It makes no difference here whether one, four, five or twelve surfaces are being machined. The range of products from HORN has provided standard tools for this purpose for decades. In the past they were almost exclusively used for machining non-ferrous metals and plastics, and only rarely employed in machining steel. The tools themselves never had an issue working with steel; it was mostly just the machines that quickly reached their limitations.

The ever-growing pressure towards cost reduction in industry, mainly in the manufacturing of series- and mass-production components, forces manufacturers to constantly review their procedures, such as the milling of multiple flat surfaces on the circumferential surface of round steel workpieces. Even small savings in time whilst manufacturing a part multiply into a considerable potential for cost reduction and increased machine capacity when it comes to more large-scale series production projects. For example, polygon milling as a replacement for conventional milling affords this kind of time-saving potential.

When employing polygon milling on lathes with tools driven in the turret, a fly cutter such as type 381 from HORN produces flat surfaces on the round circumferential surface of the part being turned. To achieve this, the workpiece in the main spindle and the rotating impact tool in the turret run in a synchronised transmission ratio. The number of surfaces produced on the workpiece depends on the tool/workpiece transmission ratio and the number of cutting edges on the tool. At a transmission ratio of 2:1, a slightly convex surface is produced. This slight form deviation is completely satisfactory for second-order surfaces such as spanner flats. Other transmission ratios produce more convex or concave surfaces. As a result, the common transmission ratio 2:1 is used in most cases. A fly cutter with 2 cutting edges produces 4 surfaces and one with 3 cutting edges produces 6 surfaces. The number of possible surfaces is unlimited.

Polygon milling – significantly faster than conventional milling

The following parameters are important for calculating the convexity of the surfaces produced: cutting edge diameter of the fly cutter, the key slot to be produced as an example, the pre-turned workpiece diameter, the number of surfaces and the workpiece/tool transmission ratio. The surfaces are produced by means of a longitudinal turning method (also longitudinal milling method) or grooving method (grooving milling method). Chamfers can also be copied. Polygon milling is generally carried out by means of counter rotation.

Flat areas on the circumferential surface could also be made by milling using the same machine, but this would take significantly more time than polygon milling with standard tools such as the type 381 from HORN. And for larger quantities of components, a significant advantage in terms of timing, multiplied by the batch size, is also a key factor for cost-effectiveness. The higher productivity achieved by this, coupled with high process reliability, creates new free machine capacity. When considering the costs of the tools for polygon milling, these tools notch up another advantage: using the same impact tool and differing only by parameter settings, other key slots can also be machined, for example.

Machine limitations

Polygon milling is a method used for decades in the production of polygonal surfaces on materials such as aluminium, brass or plastics. HORN has also offered the tools required for this process in their product range for decades. However, in many cases, the method put excessive strain on the stability and drive power of the drives for the impact tools in the turret when machining steel. A rigid and robust machine base with enhanced drive power and high drive torque for the special polygon milling tools are important for polygon milling steel-based materials. Those looking for such a robust lathe meeting these criteria should therefore consider the advantages of polygon milling with its cost-reducing benefits when it comes to machining steel-based materials.

With polygon milling, you can efficiently produce polygonal surfaces on the circumference of parts being turned.

TURNING HEXAGONAL NUTS

Productivity increases in parts from large-scale series production

Hexagonal nuts must be manufactured as fastening elements for plug connections in the shortest possible time and in high quantities. A polygon milling tool from HORN plays a key role in meeting this challenge.

The first wire spring contact, a “spring connector pin”, launched a successful company history in Berlin in 1942. Otto Dunkel had his “connector idea” patented, laying the foundation for a company which now employs around 1650 people, 950 of whom are at the company's headquarters in the Bavarian town of Mühldorf am Inn. Today connectors made by ODU GmbH & Co. KG provide a reliable transmission method for power, signals, data and media in areas such as medicine, the military and security industry, e-mobility, energy technology, industrial electronics, measuring and testing technology and more.

The fly cutter produces the hexagon for five nuts in just one single process.

Ready-to-use SW17 hexagonal nuts.

Components with high quality requirements

Communicating in a way which is oriented to customers and markets is a key ingredient in ODU's recipe for success. To secure these advantages, investments are continually made in new machines and technologies in order to respond quickly with a steep manufacturing depth. The associated time and cost pressure constantly poses new challenges for the staff running the turning plant, such as the manufacturing of hexagonal nuts from MS58 brass. The previous machining method – for key slots in particular – urgently required improvement for reasons of quantities, part variations and accuracy. Hans Hartinger, head of the turning plant, also discussed this plan with Michael Götze from Technical Advise and Sales at HORN. The machining specialist, who has already resolved numerous machining issues during his time at ODU, recommended polygon milling using tools from HORN for the manufacturing of hexagonal nuts, which previously determined essential operation time.

Polygon milling as a manufacturing alternative

When manufacturing polygons on lathes, multiple carbide cutting edges produce the surfaces on the parts being turned. The number of surfaces produced depends on the transmission ratio (i) between the counter-rotated workpiece and tool, as well as the number of cutting edges. If i = 2:1, slightly convex polygonal surfaces are produced, which are completely satisfactory for spanner flats. If i = 1:1 or 3:1, highly concave surfaces are produced which are not suitable for spanner flats. It is therefore advisable to manufacture 3, 4, 5, 6 or 8 edges with 1 to 4-bladed fly cutter while i = 2:1. The surfaces can be produced using the grooving or longitudinal turning method. Simultaneous deburring is also available.

Jointly formulated manufacturing process

Based on the plans of Josef Schmid, head of production at the turning plant, Peter Ortmaier, setup optimisation and Georg Steiglechner, the team leader, the machining of the hexagonal nuts with M7 to M18 internal threads was defined: polygon milling, internal drilling, boring out, longitudinal turning, thread chasing and parting off. For this purpose, it is advisable to use the type 381 fly cutter, type 111 for boring out and chamfering the internal drilling hole, as well as type 111 thread-turning cutting inserts for manufacturing the internal thread, from the HORN product range. Furthermore, an ODU brand parting-off blade should be used for parting off the nuts.

(from left) Josef Schmid, head of production at the turning plant, Georg Steiglechner, team leader, Peter Ostermaier, setup optimisation, Michael Götze from HORN and Peter Ortmaier, setup optimisation, are delighted after resolving yet another machining project.

Impressive machining time and tool life

A good example of the new strategy is the manufacturing of a hexagonal nut from MS58 with SW17 key slot. "Our aim was to produce a ready-to-use part in 6 to 10 seconds", explains Peter Ortmaier regarding the manufacturing and financial circumstances for the annual requirement for up to one million nuts of each type. These quantities were also critical for production in the "5-pack", starting from a rod with a diameter of 19 mm (0.7480") and a length of 3 m (0.1181"). However, this came with a compromise between high productivity, tool life and the slight burring produced by parting off. This burring was then removed by additional longitudinal turning. A Tornos DECO 20 was provided to meet the machine requirements. For key production processes, the tools were supplied by HORN.

After a number of test runs with adjustments to the cutting parameters, the following cutting data was selected for polygon milling in the longitudinal method::

	Workpiece	Tool
Number of revolutions (n) (rpm)	3.600	7.200
Feed rate (f) (mm/rev)		0,1
Cutting speed (vc) (m/min)		2.002

The tool life achieved with these parameters are notable. "With a tool cutting edge – a type 381 fly cutter features three type 314 indexable inserts – we produce over 500,000 nuts", elaborates Josef Schmid. With reference to achieving even shorter machining times, Georg Steiglechner adds: "This would be possible, but the driven tools pose certain limitations."

Polygon milling proves successful

Compared with the competitor brand's tool we used previously, production of nuts is now running quicker and more reliably. "Thanks to the reliability of the machine, the HORN fly cutters and type 111 cutting inserts, dimensional checking on the nuts, including personnel costs, has been reduced. The long automatic lathe is therefore a competitive asset because it requires proportionally less investment than multi-spindle technology", continues Josef Schmid. Because the employees of ODU offer lots of expertise in the optimisation of production processes, they design and grind the required tools themselves for special nut designs. In close cooperation with the specialists at HORN, they develop tool concepts and machining strategies which not only provide a cost-effective solution for the manufacturing of various parts and batch sizes, but also enable a very quick response thanks to short lines of communication.

Tools made using monocrystalline diamond are used for the brilliant-finish machining of (lead-free) brass.

LEAD-FREE BRASS

One material moves into the spotlight

The requirements for geometrically precise surfaces on brass components up to a brilliant finish for high-quality fittings, lifestyle products, in the automotive and electronics industry, and up to precise mirror surfaces for use in fields such as astrophysics, are noticeably increasing. The use of lead-free copper materials, particularly as an antibacterial alternative material with higher strength and oxidation resistance for the food, drink and sanitary industries, is also of increasing importance thanks to the new EU drinking-water Directive.

Increased tool wear

Copper-based materials such as brass have traditionally been alloyed with lead to improve machinability. However, changes in legislation marked a widespread ban on lead. The resulting lack of lead then had significantly negative consequences for the machinability of these materials. The result was higher tool wear due to adhesion and smeared materials, formation of long ribbon and snarl chips, and ultimately lower process reliability coupled with decreased productivity. Over the past few years, a range of lead-free or low-lead-content copper materials have been developed in order to satisfy new legal requirements. A well-known example is the brass variation CuZn21Si3P under the brand name “Ecobrass” or “Cuphin”, as well as other special brass grades such as the wrought alloy CuZn10Si4, the casting variation CuZn10Si4-C and many more.

Generally, higher specific cutting forces and tool temperatures are specified for the lead-free brass materials. These are on average double or triple that of conventional CuZn39Pb3 free-cutting brass. Heavy smearing of materials on the chip breaker and flank, particularly when machining CuCr1Zn, leads to TiAlN layers becoming torn out, leaving the carbide substrate exposed. Likewise, sharp-edged, coated cutting edges are also subject to types of wear such as initial wear as a result of micro-cracks. This is because of the high adhesive tendency of lead-free Cu materials and the high cutting forces used.

Diamond as a solution

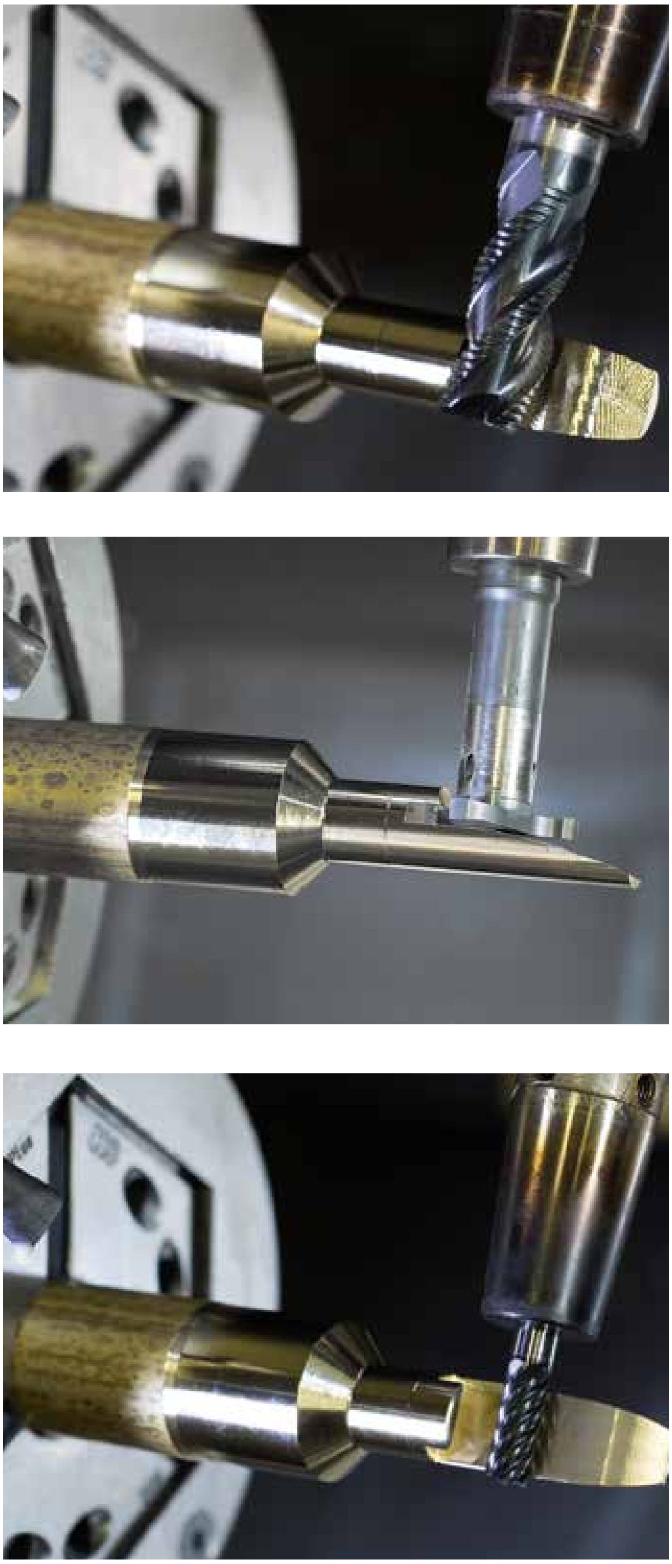
Compared with TiAlN coatings, diamond layers or diamond cutting materials have a significantly smoother surface, a lower friction value, the lowest adhesive tendency and a significantly higher thermal conductivity. Moreover, diamond coatings or cutting edges offer excellent resistance to abrasive wear owing to their hardness, meaning that they are also the best option for dry machining. The cutting speeds are multiple times that of TiAlN-coated cutting edges.

With their high thermal conductivity, they also reduce heat transfer into the workpiece, which improves form and dimensional accuracy particularly for small and geometrically complex components. Higher heat transfer into the workpiece, such as when machining CuZn39Pb3, was previously prevented by its friction-minimising lead film and today must be prevented by using different cutting materials with other properties.

Whilst ceramic cutting materials are unsuitable because of their high adhesive tendency and low thermal conductivity, diamond-coated cutting edges and cutting materials such as PCD, CVD diamond and MCD have proved their worth thanks to their even higher performance profile. The latter is unrivalled in the production of high-precision mirror-finish surfaces. Depending on the Cu material or machining type, PCD or CVD diamond has proved to be the cutting material of choice. The various PCD varieties with custom-ground cutting edge geometries are tailor-made to meet the relevant requirement profiles. CVD diamond cutting edges with the highest hardness, precision-lasered and extremely sharp cutting edges and lasered chip breakers ensure safe chip-breaking even in dry machining, and low chip thickness, high-precision surfaces and low burr formation.

Extensive range of cutting materials

With these cutting materials perfectly adapted to the machining task, a significant enhancement of tool life, geometric accuracy, surface quality, chipping capacity, productivity and, above all, reliability is achieved. The tool specialist HORN from Tübingen has long been responsive to the requirements of those who work with lead-free copper alloys and offered them the customised, productive, safe and cost-effective solution with its extensive range of cutting materials.



Rough milling (image 1), groove milling by circular interpolation (image 2) and finish milling (image 3): lead-free brass, like almost any material, offers a wide spectrum of possible machining operations.

HORN is at home in more than 70 countries in the world

GROOVING • PARTING OFF • GROOVE MILLING • BROACHING • PROFILE MILLING • REAMING

Subsidiaries or representatives

Hartmetall-Werkzeugfabrik
Paul Horn GmbH
Postfach 17 20
72007 Tübingen
Tel.: +49 7071 7004-0
Fax: +49 7071 72893
E-Mail: info@phorn.de
www.phorn.de

BLUECOMPETENCE
Alliance Member
Partner of the Engineering Industry Sustainability Initiative

HORN S.A.S.
665, Av. Blaise Pascal
Bat Anagonda III
F-77127 Lieusaint
Tel.: +33 1 64885958
Fax: +33 1 64886049
E-Mail: infos@horn.fr
www.horn.fr

HORN CUTTING TOOLS LTD.
32 New Street
Ringwood, Hampshire
GB-BH24 3AD, England
Tel.: +44 1425 481800
Fax: +44 1425 481890
E-Mail: info@phorn.co.uk
www.phorn.co.uk

HORN USA, Inc.
Suite 205
320, Premier Court
USA-Franklin, TN 37067
Tel.: +1 615 771-4100
Fax: +1 615 771-4101
E-Mail: sales@hornusa.com
www.hornusa.com

HORN Magyarország Kft.
Gesztenyefa u. 4
HU-9027 Györ
Tel.: +36 96 550531
Fax: +36 96 550532
E-Mail: technik@phorn.hu
www.phorn.hu

FEBAMETAL S.p.a.
Via Grandi, 15
I-10095 Grugliasco
Tel.: +39 011 7701412
Fax: +39 011 7701524
E-Mail: febametal@febametal.com
www.febametal.com

SK Technik spol. s.r.o.
Jarni 1052/44k
CZ-614 00 Brno
Tel.: +420 545 429 512
Fax: +420 545 211 275
E-Mail: info@sktechnik.cz
www.sktechnik.cz

HORN Trading Co. Ltd
Room 905, No. 518 Anyuan Rd.
CN-200060 Shanghai
Tel.: +86 21 52833505
Fax: +86 21 52832562
E-Mail: info@phorn.cn
www.phorn.com/chn