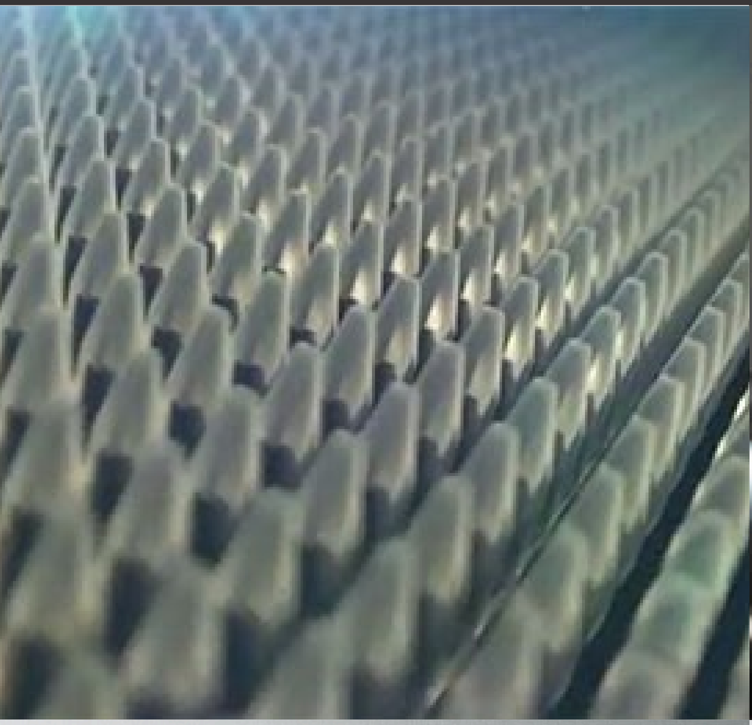
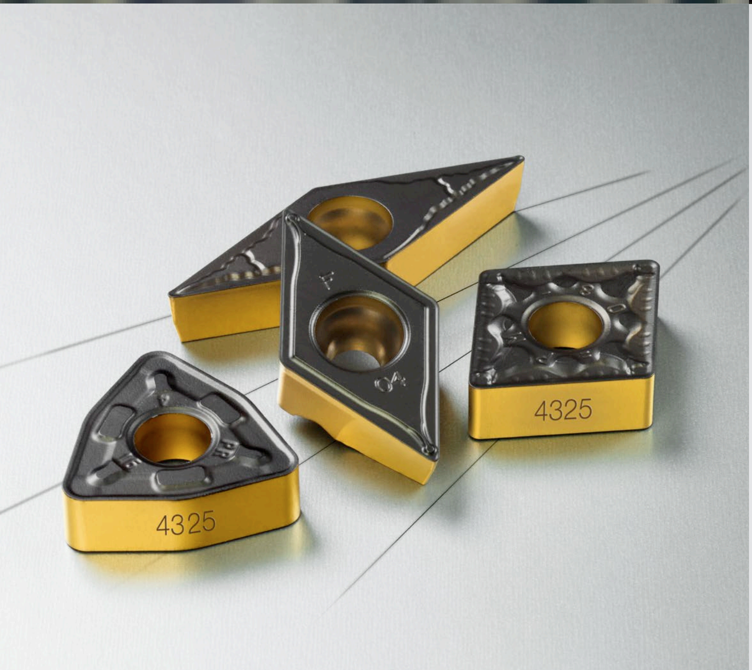
Steel turning endurance





New innovation delivers best practice solutions to daily machining challenges

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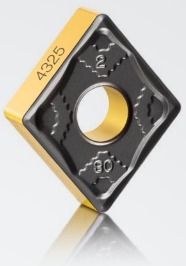
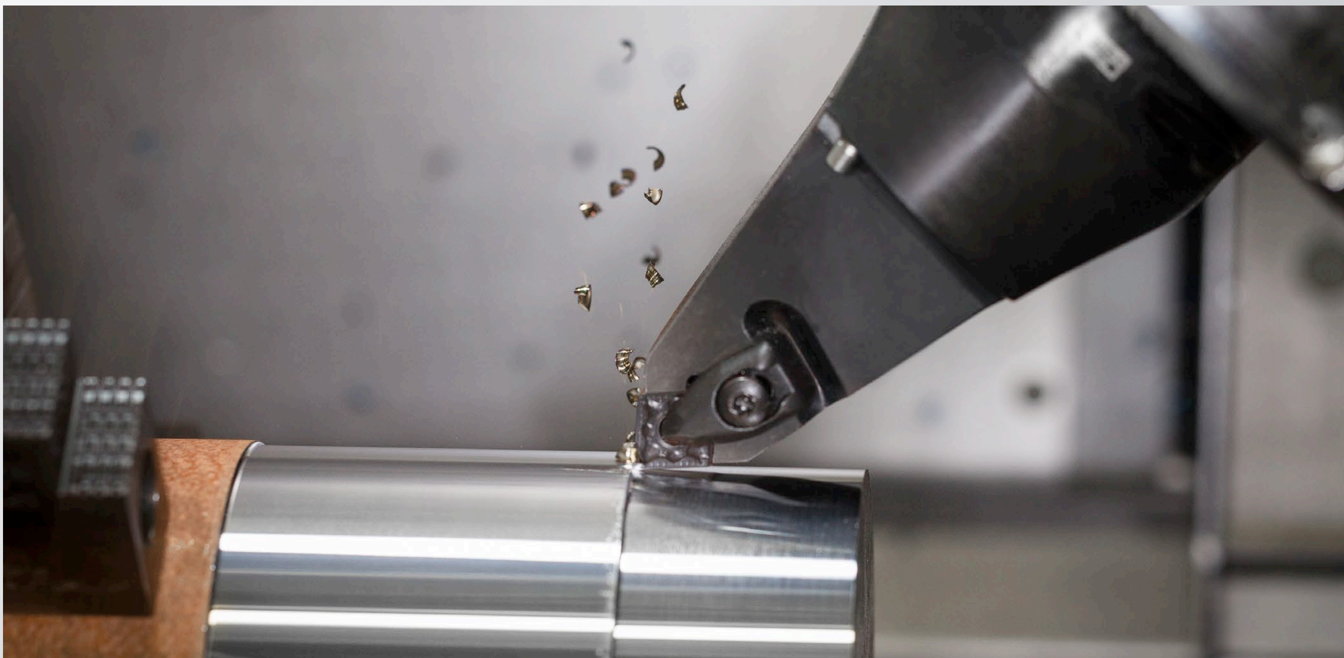


Inveio™
Uni-directional crystal orientation

Engineers and workshop managers are under constant pressure to reduce cycle times, increase productivity and improve security in all aspects of manufacturing. However, achieving gains in a process such as steel turning, arguably the most common of all machining operations, has proved challenging in recent years – until now. This whitepaper will examine new advances in material science that are allowing the latest insert grades for steel turning to demonstrate never-before witnessed levels of endurance at manufacturers around the world. Moreover real machine shop challenges are referenced and it is also shown how they were overcome. The impressive gains that were achieved as a result are now available to everyone in the machining community prepared to embrace the concept of ground-breaking innovation.

Predictability has become increasingly important in modern turning, especially where there is limited supervision in production. Unfortunately, there will always be a number of threats to the insert edge line during steel turning. For instance, one challenge is the breadth of the ISO P25 application area, which includes several very different materials, from ductile low carbon steels to high alloy hard steels, bar material to forgings, and castings to pre-machined parts.

With this in mind, the biggest time killers in modern production are insert changes, production interruptions and finding the right insert for each application or material. GC4325, a single, long life insert for the entire ISO P25 area provides the solution through more parts per edge and fewer stops for insert changes. What's more, the same extended tool life every time means no sudden breakages and less rework and scrap. The good news for engineers is that all of this is in addition to the ability of GC4325 to run at higher cutting data.



So, how is this possible? Well, the insert substrate and coating of GC4325 are highly capable of maintaining the insert edge line at higher temperatures, which translates into the potential for higher cutting speeds with added security through more predictable, longer tool life. As a result, an average productivity increase of 30 per cent over other existing technologies is now readily available.

Ultimately, GC4325 offers a new level of performance with coated cemented-carbide indexable inserts across a large and diversified application area. What's more, these claims are now being substantiated by a host of machining companies around the world, proving the technology's ability to overcome everyday challenges in steel turning.

Customer success

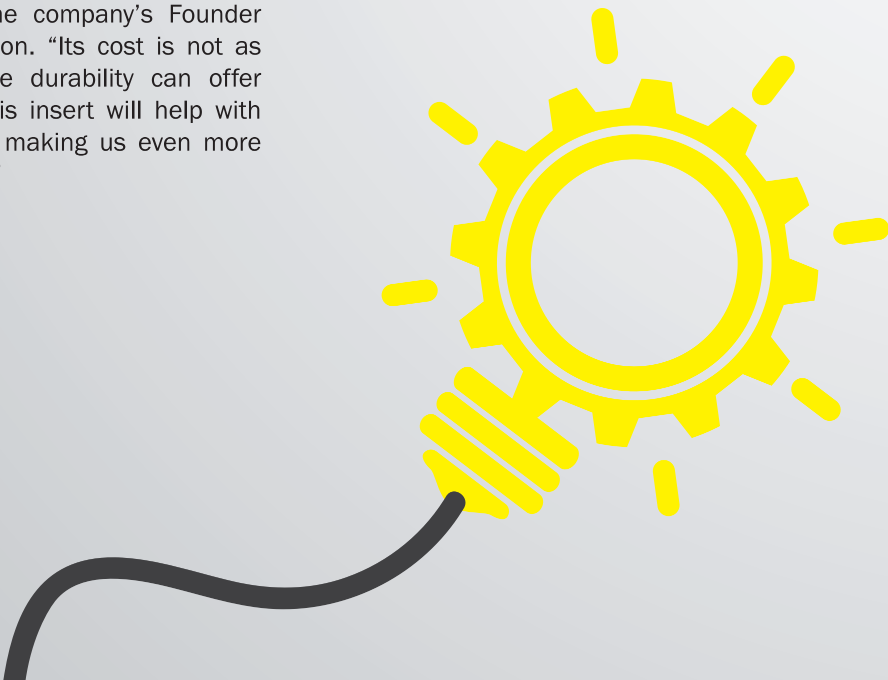
Among the early adopters of GC4325 is Bifrangi SpA, a 430-employee producer of machined steel forgings for the automotive industry. Based at Mussolente near Vicenza, Italy, the company's customers include auto giants such as BMW, Getrag and Deutz to name but a few.

Using a Famar CNC vertical turning lathe featuring a Coromant Capto C4 coupling, the task involves roughing a 200 mm diameter automotive hub. External axial turning and facing operations are required on a workpiece made from forged steel (CMC code 02.1). With a time-in-cut of 26 seconds per part, Bifrangi could achieve 116 components using the previous generation grade GC4225 before the insert required replacement. However, using the new GC4325 grade in the same style (CNMG square inserts with PR chip breaker geometry), the company can now achieve 160 components, thus demonstrating a 38% increase in tool life. The cutting parameters are identical: 200 m/min cutting speed; 318 rpm spindle speed; 0.36 mm/rev feed; and 2 mm depth of cut.

"GC4325 gives us good opportunities to improve our machining processes," says the company's Founder and President, Francesco Biasion. "Its cost is not as important as tool life because durability can offer financial benefits. Ultimately this insert will help with the growth of our business by making us even more competitive in the marketplace."

Combining high cutting data capability with a proven tool life increase is the key to GC4325. Put simply, the grade just keeps going and going, as the Gurgaon, India facility of Bajaj Motors can testify. Bajaj Motors turns critical transmission forgings for automotive customers such as Tata, Hero MotoCorp, Suzuki, Mahindra, Nissan and Renault.

"When Sandvik Coromant said the new GC4325 grade would offer a 20-25% improvement over our best running grade, we didn't believe them," states Tarun Bhargava, General Manager (Engineering) at Bajaj. "Even when they showed us the results, we thought there might be some manipulation involved. So we ran trials on two different machines and the outcome was the same both times. As a result, we are now using GC4325 to reduce our cost per component, which will also improve our profit margins."



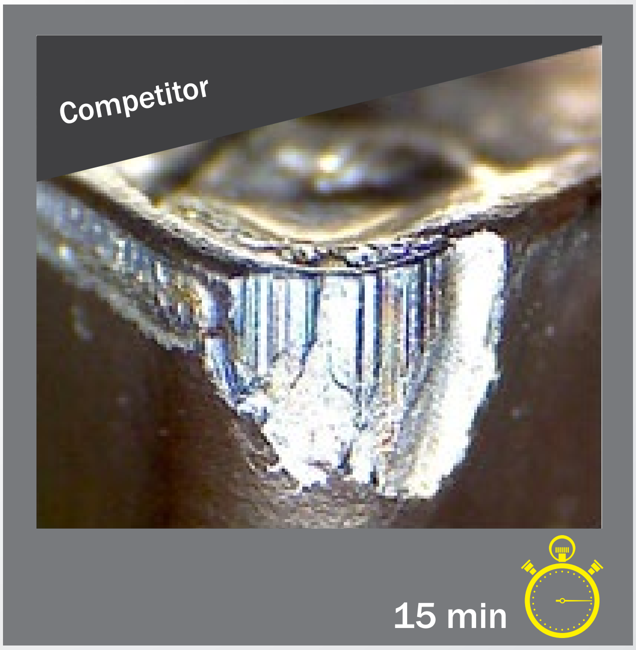
Controlled wear mechanisms

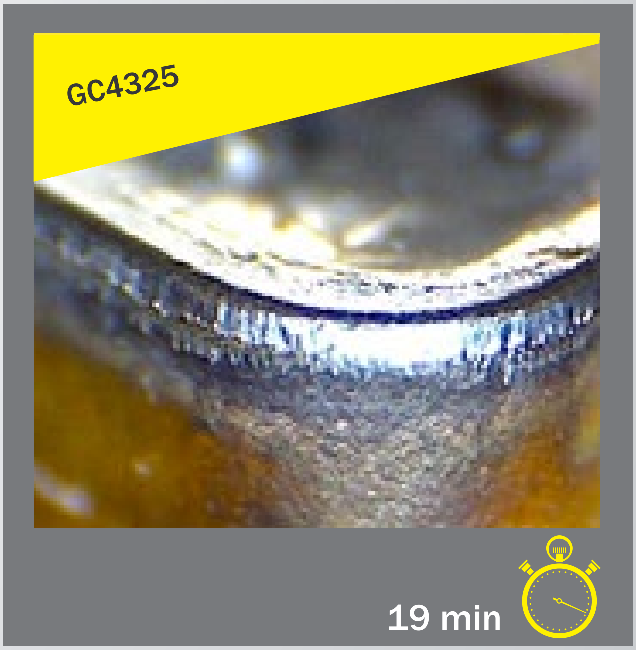
In truth, insert wear will always be unavoidable, but the key is being able to limit and control it. This is a major advantage of GC4325: a stronger edge line that lets machine shops run machines at night, or keeps them going smoothly without stopping, all day long.

As a representative example, one type of material where GC4325 has exceeded expectations is the steel used for bearings. These specifically challenge the cutting edge, often generating rapid crater wear. With this in mind, Sandvik Coromant has developed the insert substrate and coating to better withstand diffusion wear at high temperatures, thus reducing the effect that causes crater development on the rake face. In this way GC4325 is also capable of maintaining an ideal fluid flow zone when generating the chip, which means being able to use a higher cutting speed but with the edge security required in unmanned machining.

GC4325 achieves its effectiveness because it is designed to tackle the mechanisms leading to premature breakdown. Essentially, this requires engineering the insert's substrate, coatings and post treatment to limit continuous, controllable wear and eliminate modes of discontinuous wear. When an insert undergoes only continuous, controllable wear, its performance will be consistent and predictable. In contrast, discontinuous wear is caused by scattered, discrete events such as the appearance of a surface crack, plastic deformation or flaking of the coating. The effects of discontinuous wear are difficult or impossible to control.

In the same conditions and after a longer time in cut, GC4325 shows less wear compared to a competitor insert grade.





Cutting edge protection

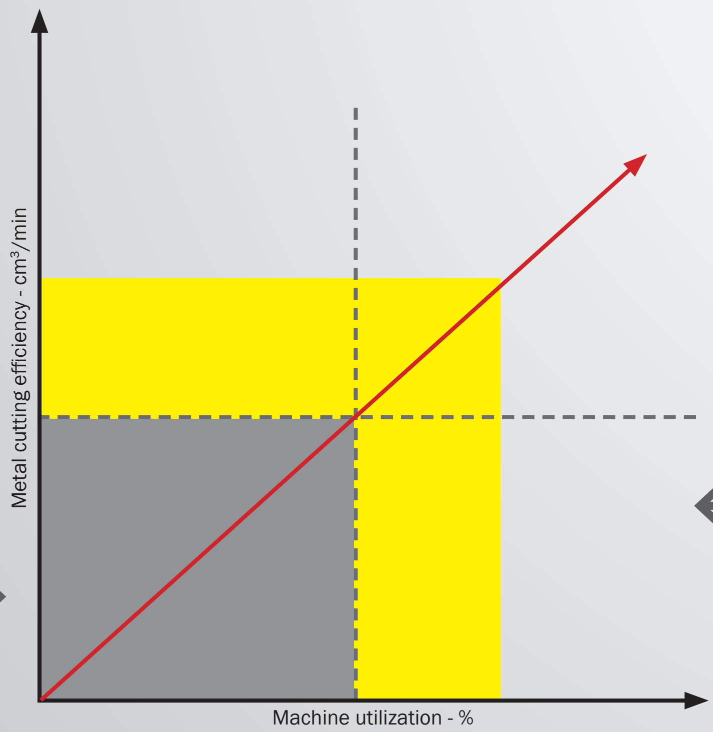
Engineers know that to be successful, turning operations in the P25 steel range must address and balance many factors. For example, unless the edge line remains intact, rapid breakdown occurs, resulting in unacceptable parts and loss of machining security. Here, fracture resistance is paramount, as is a cutting edge possessing the necessary hardness to resist plastic deformation induced by the extreme temperatures encountered in P25 cutting zones. Furthermore, the insert coating must adhere tightly to the substrate. If the coating fails to stick, exposed substrate deteriorates rapidly.

Observations of insert behaviour find that the optimum wear pattern for any insert is controlled flank wear because it protects cutting edges. Flank wear is caused by abrasion of the clearance face below the edge line, while abrasion results from the passage of the chip as it forms during cutting. Flank wear is the natural depletion of material, and is acceptable to the extent that other wear modes are kept in check.

Another common wear pattern that is controllable is cratering. Crater wear occurs in steel turning because of heat and pressure. Like flank wear, some crater wear is acceptable to the extent that it does not weaken the cutting edge. Both crater wear and flank wear are common in steel turning, and as long as it is only these wear patterns being experienced – and controlled – the process offers potential for high productivity. Other factors that help determine a successful outcome include micro and macro geometry, nose radius, insert size and shape. The combination of these with the insert grade determines optimized turning operations.

Depending on the application, higher metal removal rates and cutting speeds of over 400 m/min can be achieved, equating to cutting data capabilities in excess of anything seen before. Market research by Sandvik Coromant indicates that the manufacturing industry's average cutting speed levels are around 70 per cent of recommended values. This of course depends partly on factors such as machine capability, workpiece diameters, operating competence and aversion to risk. However, for a machine shop making full use of existing cutting techniques, up to 30 per cent additional productivity is available through GC4325. In short, the advances achievable with the new grade actually help users resist holding back on cutting data levels.

GC4325 is capable of running at cutting data higher than almost all other P25 grades: productivity through metal cutting efficiency.



A 10-200% increase in tool life has been seen with GC4325 (average >30%): productivity through increased machine utilization.

Tool life tripled

A good example can be seen at a machine shop in Germany, where the use of a GC4325 grade insert on an automotive housing made from forged carbon steel C60V (250 HB) is seeing the number of components per edge triple. In comparison with a competitor insert, the GC4325 grade insert machines 45 housings per edge, against just 15 previously. Furthermore, cutting data has been increased by 30 per cent to 180 m/min cutting speed and 0.4 mm/rev feed rate. Depth of cut is 3 mm.

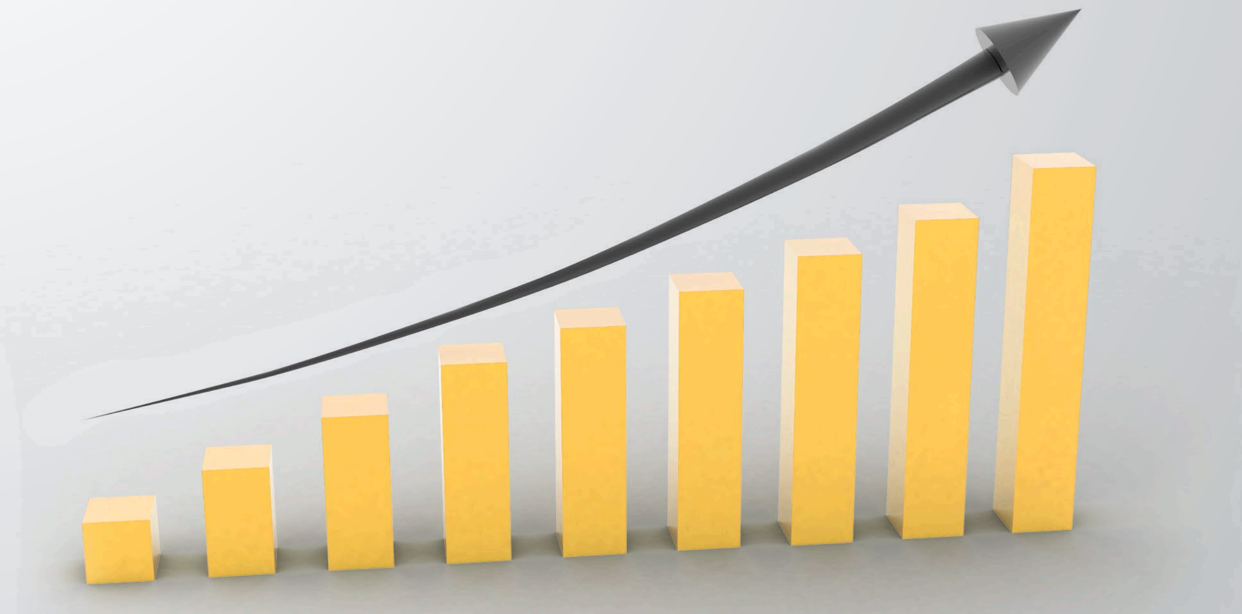
More modest but still impressive gains are also being achieved on a wheel hub machining operation in the UK. Made from cast alloy steel DIN38MnVS6 (250 HB), GC4325 makes it possible to machine 100 wheel hubs per edge at 2 mm depth of cut instead of just 60 hubs, delivering a 67 per cent increase. Engineers are now looking at accelerating the process from its existing 180 m/min and 0.37 mm/rev feed.

Elsewhere, a Brazilian manufacturer of automotive spheres has overcome the challenge of machining forged carbon steel SAE 1045 (235 HB) by using GC4325 grade inserts to balance high insert utilization with good levels of safety. The move is delivering 34 per cent more parts per edge – invaluable in this high volume application. The cutting speed is 250 m/min while feed rate is 0.35 mm/rev. Similarly, at a machine shop in India turning crankshafts for the two-wheeler market, burr formation was proving a particular problem on forged alloy steel JIS SCM430 (320 HB). However, not only is the customer seeing a gain of 43 per cent more parts per edge using GC4325 grade inserts, but burr formation is delayed for another 20 components thanks to a cutting edge that remains intact for longer.

Automotive gears can also benefit, as one customer can testify after changing to GC4325 – a move that means the machine can run much longer before needing to change insert, saving hours in production time per year. The application involves the external axial turning and facing of gears made from low alloy steel, P2.1.Z.aN (200 HB). Not only has tool life been boosted by 159 per cent (220 parts per edge compared with 85 previously using a competitor insert), but cutting speed has also been increased by 50 per cent, from 300 to 450 m/min.

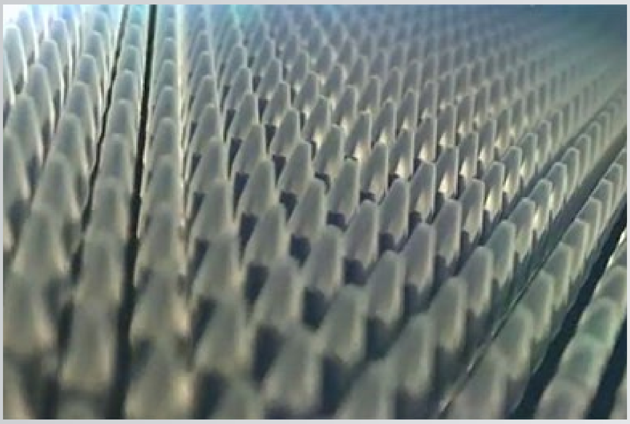
Of course, there are plenty of sectors beyond automotive that can benefit from greater steel turning endurance. A case in point is the oil and gas industry. For instance, a Chinese machine shop rough-turning shafts for the oil and gas sector at 4.5 mm depth of cut has seen the number of parts produced per edge double using GC4325 grade inserts. The material is forged alloy steel 42CrMo (280 HB).

In Italy, another energy sector specialist is enjoying gains of 33 per cent more parts per edge when machining oil and gas valves made from rolled carbon steel LF2. Using a GC4325 insert, the company can now complete two components in 23 minutes with only small signs of wear, in comparison with 1.5 parts in 17 minutes using a competitor insert. The cutting data includes 350 m/min cutting speed, 0.39 mm/rev feed and 3 mm depth of cut.



Uni-directional crystals

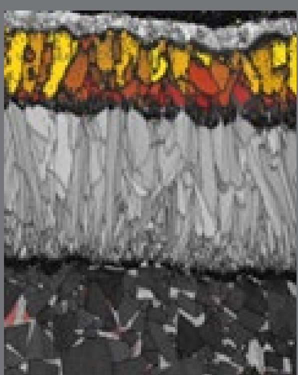
GC4325 is proving a highly effective platform for overcoming all of these challenges. In essence, the grade comprises a carbide substrate, a layer of TiCN (titanium carbonitride), a layer of Al_2O_3 (aluminium oxide) and a layer of TiN (titanium nitride). The nature of the crystalline structure within the layer of aluminium oxide is unique. Here, the crystals are arranged uni-directionally with the longest facets in a near parallel position. In addition, all of the crystals are oriented with the densest atomic plane toward the cutting surface. This 'heads up' orientation makes the aluminium oxide layer very hard, allowing it to resist wear exceptionally well.



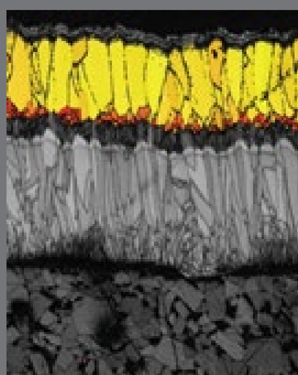
Known as Inveio™, this crystal orientation enables the layer to act as a barrier to heat from the cutting zone. The dense atomic plane nearest the surface deflects heat into the chip and coolant. Meanwhile, the heat that is absorbed by the insert is conducted to the less dense atomic planes nearest the TiCN coating, where it dissipates into this layer and the substrate beneath. By preventing the build-up of heat, plastic deformation is forestalled because the surface of the insert does not get hot enough to lose its original shape.

The successful production of inserts based on the GC4325 grade hinges on the advanced control of the chemical vapour deposition (CVD) process that forms each layer of the coating. In addition, other aspects of the manufacturing process contribute to or support the functionality of the special nature of the aluminium oxide layer. For one, the structure of the carbide substrate features a cobalt-enriched surface gradient zone that acts as a thin outer layer which is slightly softer than the inner core. This provides an impact-absorbing 'padding' for the coated layers. The inner core of the substrate however, retains its tough, wear-resistant properties derived from the fine grains of tungsten carbide and cobalt binder.

Secondly, Sandvik Coromant has developed methods to produce an edge line with a highly uniform radius. With most known methods on the market, this radius varies by as much as ±15 µm. Now, the deviation band is less than one third as wide. Greater uniformity enhances the predictability of edge performance and helps retain sharpness. Lastly, the top surface of the finished insert is subjected to a post treatment that can smooth and blend its texture while removing the TiN coating where it is not needed. In addition, this treatment alters the residual stress between the coatings and the substrate: tensile stress is reduced; compressive stress is enhanced. The result is tighter adhesion between the remaining coatings and substrate.



In conventional CVD alumina coatings, the crystal orientation is random.



With Inveio™, every crystal in the alumina coating is lined up in the same direction, towards the top surface.

Even greater endurance

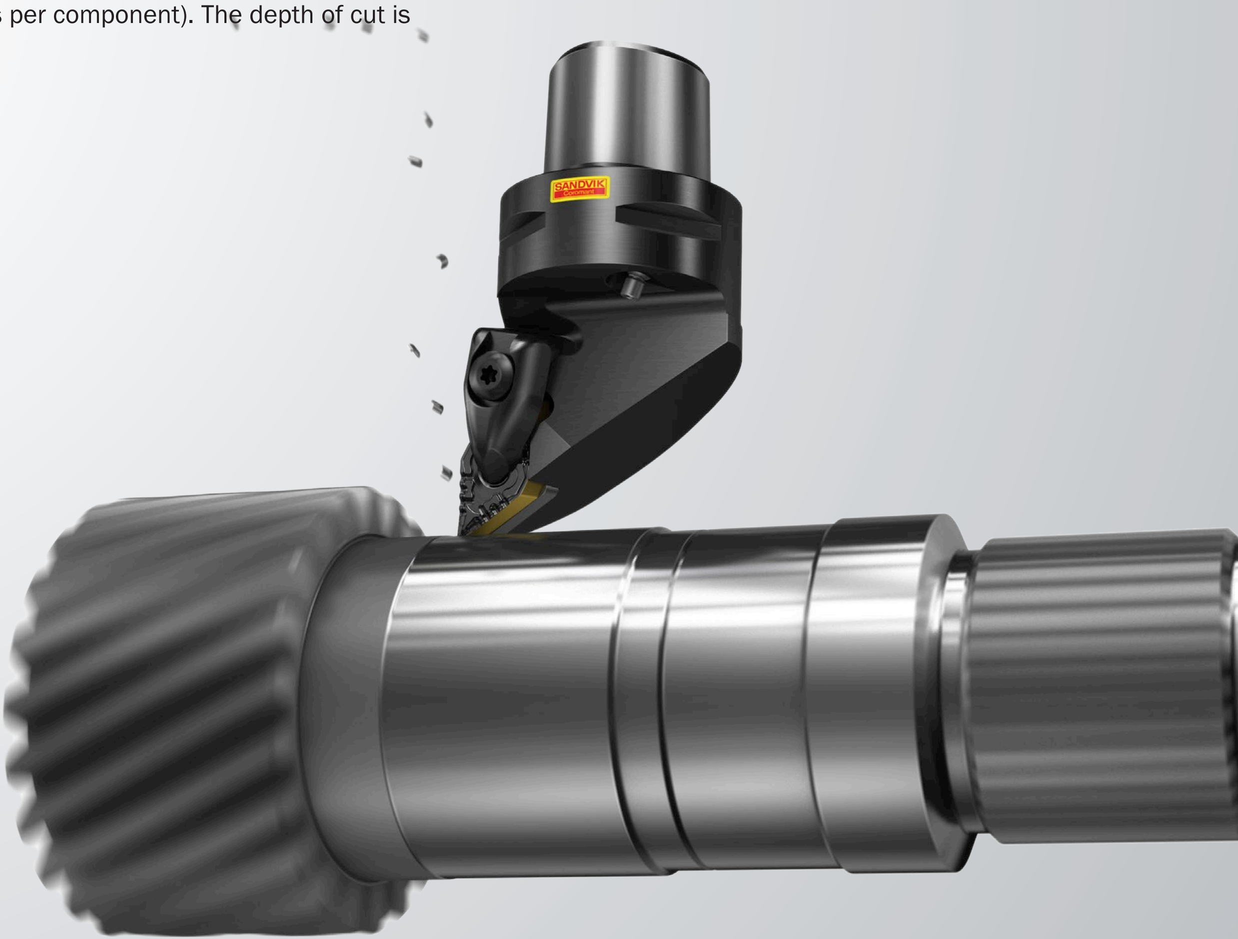
The success of GC4325 since its launch in October 2013 has been unprecedented. However, to support the theme of endurance in steel turning further, GC4315 was introduced in March 2014 as the preferred choice where even higher speeds and even longer times in cut are demanded.

Designed as an optimiser in the ISO P15 application area, GC4315 is able to withstand extremely high cutting temperatures to allow greater metal removal rates without compromising tool life. Like GC4325, the grade is equipped with Inveio™ uni-directional crystal orientation. Highly suitable for unmanned mass production even in hard workpiece materials, GC4315 can be applied to external and internal turning, roughing and finishing, wet and dry machining, and continuous to light-interrupted cuts.

In a customer application on an adaptor housing made from low alloy steel (335 HB), GC4315 is demonstrating impressive results. The insert machines two complete components (external, axial and face turning) whereas an established competitor insert manages only 1.2 parts. This is due to the better crater wear demonstrated by the new grade, which is crucial at such a long time in cut (19.24 minutes per component). The depth of cut is 3 mm.

Equally impressive results are being achieved by another customer, this time involving external profile turning on a low alloy steel (200 HB) driveshaft. At a cutting speed of 350 m/min, GC4315 shows better flank wear resistance and edge line security compared with a competitor insert, which exhibits worn coating and exposed substrate.

Elsewhere, another automotive customer machining piston covers is finding that GC4315 completes 20 components compared with 17 using a competitor insert. This is thanks to the improved abrasive crater wear resistance which enables GC4315 to better withstand the heat generated when machining the low alloy steel, P2.5.Z.HT (310 HB) material. Furthermore, cutting speed has been be increased from 180 m/min to 200 m/min, while deeper cuts of 2.5 mm can also be taken, compared with 2.0 mm previously.



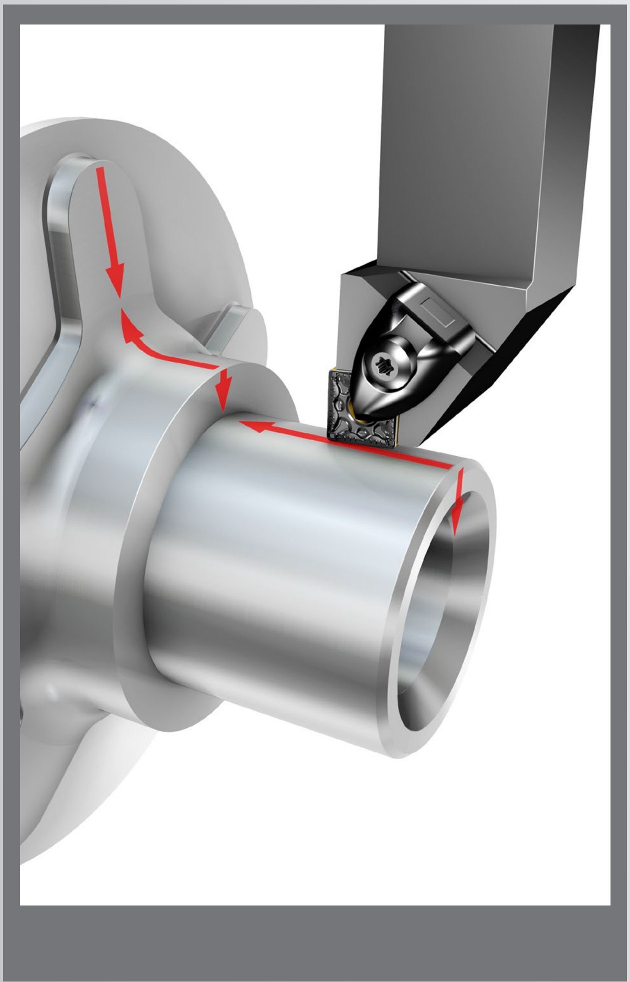
Strategy to succeed

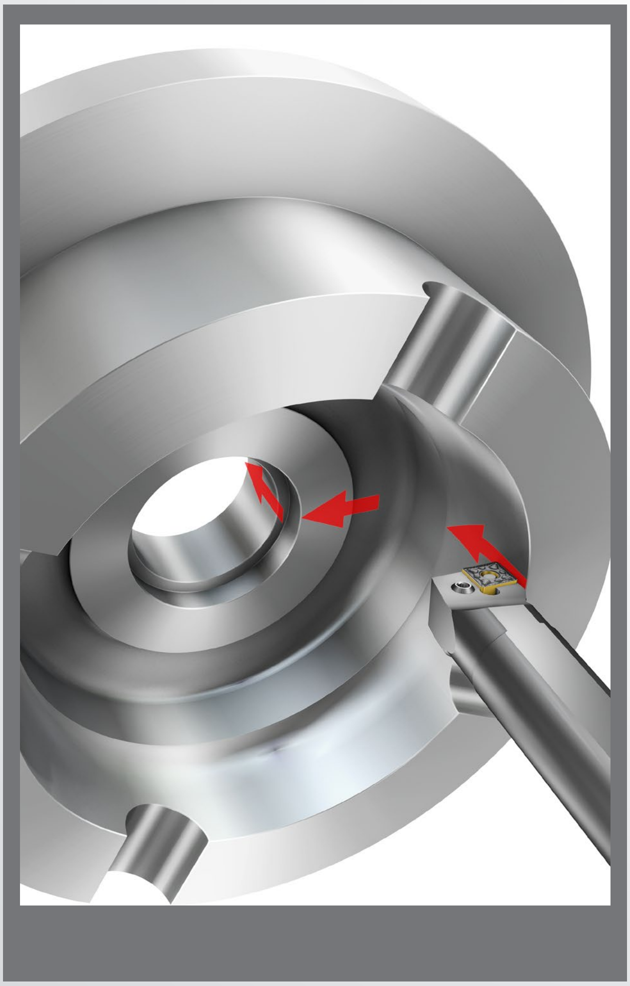
Many might consider the turning of the so-called 'softer' steels in the P25 area to be fairly straightforward, but in reality the ductility of materials such as low carbon steel can often cause larger, inconsistent chips which limit success. As a result, good chip forming and breaking is the key to maintaining high productivity levels in these materials.

The relationship between cutting depth and the insert nose radius has a big influence on the level of chip breaking that can be achieved. For best results in this area, machine shops should try to achieve a cutting depth bigger than, or at least close to the nose radius value.

Feed rates, when machining low carbon steels also have a big influence on chip breaking. A low feed rate will result in thin chips which are very hard to break. Low feeds, in combination with smaller cutting depths also mean that the chip is not able to reach the chip breaker. To solve these problems, always aim for the highest feed possible, taking into consideration the stability of the workpiece, tool, clamping and surface finish requirements.

For best chip forming performance, always choose a cutting direction which provides an effective entering angle as close to 90° as possible – back turning should be avoided as this gives a very small effective entering angle. Better chip formation can be achieved with a downwards cutting direction on the workpiece, which also minimizes the risk of vibration.

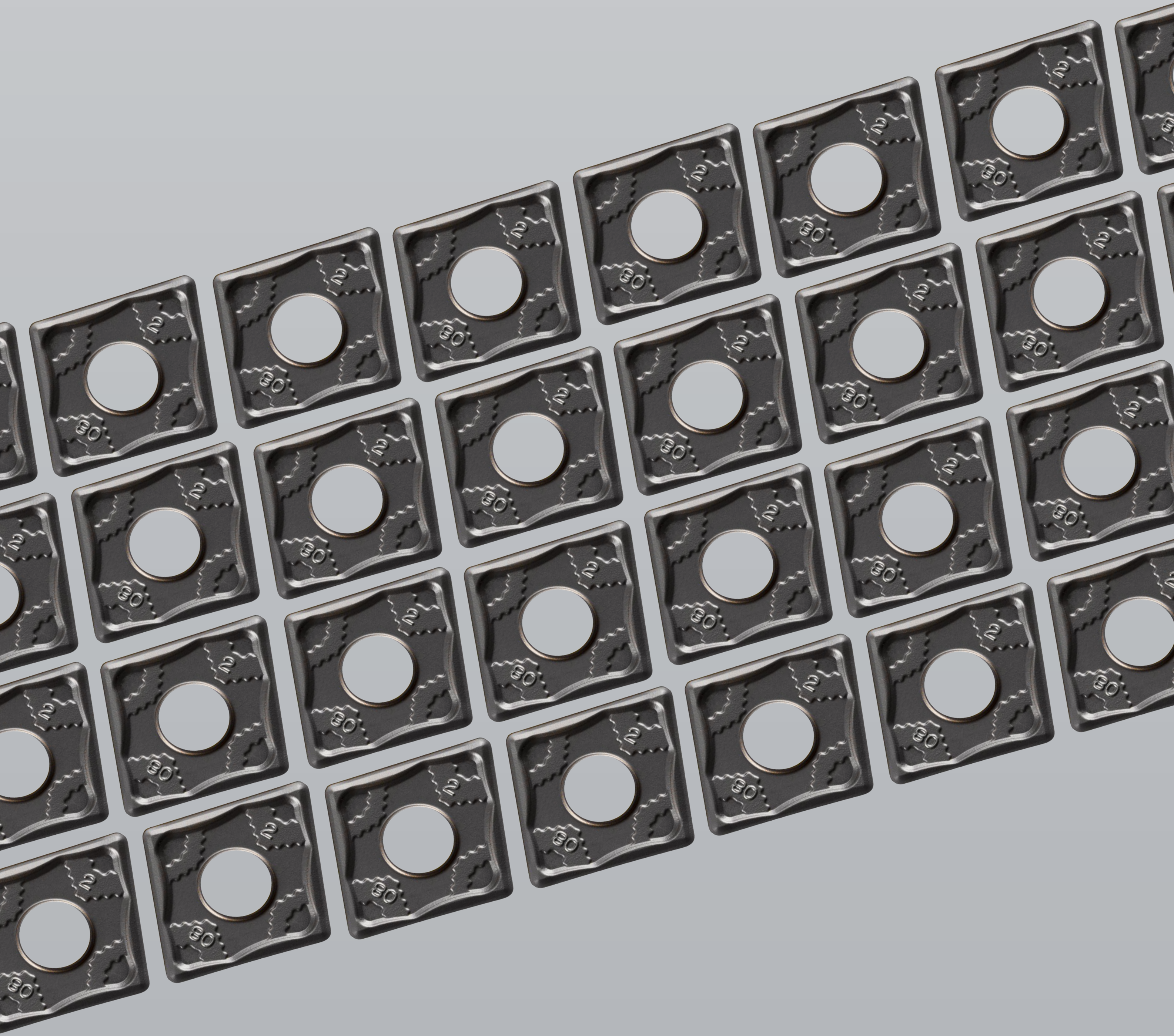




Critical selection

Clearly, process variables in steel turning applications are critical, especially in the choice of turning inserts. Many factors must be addressed and balanced when selecting the insert grades intended to yield optimal results.

In the past, process engineers made strategic trade-offs between material removal rates, tool life and risk of process disruptions. Today, however, an overriding consideration is often how to accommodate processes that take advantage of turning equipment designed for low operator involvement. The operator may be present, but assigned to monitor and tend multiple machines. Or, the operator may not be present at all, having set up the machine for operation through an unattended shift, overnight or at the weekend. In such an environment, the reliability and predictability of the cutting tool's performance take on heightened importance. With GC4325 and GC4315, Sandvik Coromant has shown its awareness of the shifting priorities in turning applications, developing insert grades that give manufacturers a genuine advantage in productivity and profitability.



Sandvik Coromant is a global leading supplier of cutting tools, tooling solutions and know-how to the metalworking industry. With extensive investments in research and development we create unique innovations and set new productivity standards together with our customers. These include the world's major automotive, aerospace and energy industries. Sandvik Coromant has 8000 employees and is represented in 130 countries. We are part of the business area Sandvik Machining Solutions within the global industrial group Sandvik.

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