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Confidence Game

Grades, geometries and a broader knowledge base make machinists less neurotic about turning exotics.

Let's face it, "exotic" materials aren't quite as exotic as they used to be. Exceptions aside, a vendor requesting that a turned part be made of titanium or a nickel-base alloy simply doesn't generate the same level of fear the way it did even 2 years ago.

Indeed, this fear was not limited to job shops but extended to toolmakers, too. Take the case of Roberts Automatic Products Inc., Chanhassen, Minn. When the firm started bidding for jobs requiring nickel-base alloys, it found its tool supplier had no tools specifically designed for the material. At first, the shop "didn't get a lot of good advice," said Bill Roberts, senior process engineer. The tool supplier's attitude, he said, could be surmised as, "Here's a bunch of tools, try'em and see what happens."

Today, the story is different—for Roberts and the industry as a whole.

Designer Edges, Smooth Chipping

"There is definitely going to be increased consumption of titanium alloys, particularly Beta-phase titanium," said Don Graham, manager of turning products for Carboloy Inc., Warren, Mich. Compared to Alpha-phase and Alpha-Beta-phase, Beta-phase alloys are considered to be the most difficult


Carboloy

Turning titanium has become progressively easier with the right tools, such as, in this case, Carboloy's CP200 PVD-coated carbide turning grade.

Swiss turns

BY BRENT GODFREY, SANDVIK COROMANT CO.

Choosing advanced tooling for Swiss-style machining.

Previously, Swiss-style machining was largely confined to watchmakers. Today, its use is expanding because medical, electronics and automotive engineers routinely design components too small and precise for conventional lathes. For example, a Swiss-style machine with modern carbide cutting tools can turn a titanium hip-joint implant just 0.2" in diameter and hold to tolerances of ±0.0004"—five times tighter than turret lathes.

Throughput doubled when the shop replaced brazed-tipped tools with uncoated carbide inserts—from 100 parts per day to 200 parts per day. Equally important, the extra-sharp, positive-rake cutting edge of the carbide inserts held consistently tight tolerances and improved surface finish from 32 R_a to 16 R_a.

Bar- or wire-fed Swiss machines can also make such parts more economically and with far better quality than is possible with the casting or extrusion process.

Further, with gang-type tooling for multiple setups, Swiss-style machines are more cost-effective than ordinary screw machines when making small quantities of parts for just-in-time manufacturing. Advanced cutting tools and precision toolholders can maximize Swiss-machining productivity and improve the quality of finished parts. For example, switching from brazed-tipped carbide parting tools to more wear-resistant, coated-carbide inserts with sharper edges reduced cycle time from 11 seconds to just 5 seconds when turning an automotive fluid connector. The 0.4"-long steel part measured less than 0.2" in diameter and required a specific geometry and surface finish to grip a hose. The resulting higher-quality finish was more uniform from batch to batch, too.

Swiss-machined parts are generally 0.02" to 2" in diameter. They can range from short screws with a 1:1 length-to-diameter ratio to 12"-long surgical pins less than 0.25" in diameter. For long, slender parts, Swiss machining is sometimes the only practical production method. Automotive engineers are incorporating Swiss-machined valves and connectors in airbags and antilock-braking systems.

The one true measure of machine tool productivity remains throughput, and modern tooling can make a dramatic difference in Swiss machining throughput, accuracy and finish. As typified in the aforementioned titanium hip-joint implant example, compared with regrinding brazed-carbide and HSS cutters, replacing indexable-carbide inserts improves the profitability and quality of Swiss machining.

Small valves, camera parts and other components are widely Swiss-machined with modern carbides and cermets. Uncoated carbide resists wear when turning titanium and other difficult-to-machine aerospace materials. Fine-grain carbide compositions provide extra-sharp cutting edges for turning stainless steels. Nickel-free cermet inserts improve the finish of alloyed steels.

Although the same carbide grades are used in conventional turning applications, productive Swiss machining requires the right combination of carbide grades and insert geometries. Cutting inserts need edges ground extra-sharp to reduce cutting pressure and potential part distortion. They also require high-positive-rake angles for lower cutting forces that enhance surface finish and accuracy.

The shape of the part dictates how low cutting forces must be. Long, slender components, those with a long overhang and parts that require a very good surface finish and exceptionally tight tolerances demand high-positive-rake inserts. Tough, sticky materials, such as stainless steels and titanium, also require positive rakes to prevent BUE.

Other keys to properly specifying inserts for Swiss-style machining include: a polished top surface, which enhances chip flow when machining difficult materials; keeping the tool setup close to the collet to minimize vibration and protect the accuracy of machined parts.

Screw-clamp toolholders designed to fit the gang-style tool setup common on Swiss machines expand the range of carbide inserts available for Swiss machining. Stronger, more rigid design and secure clamping make it possible to turn and groove with a single tool.

Sandvik Coromant

Tools for Swiss-type machines make small precision components for the medical, automotive and electronics industries.

Knowledgeable tool suppliers can help even experienced machinists optimize their Swiss tooling, setups and machine settings. Sandvik's technical specialists, for example, conduct several hundred productivity-improvement programs a year, free of charge. They audit machines and cutting tools and analyze manufacturing routines to recommend coordinated process changes.

Experience shows such partnerships to boost machining throughput 20 percent on average and generate substantial savings in machining time, maintenance, repair, operating costs and tooling inventories. When faced with the special demands of Swiss machining, the added insight and technical assistance can generate even bigger savings.

For additional information on turning, go to "Article Search" at ***www.ctemag.com*** *and select the Turning category. For more information on Sandvik and its products, visit the company's Web site at www.coromant.sandvik.com.*

to machine. “Their mechanical properties are dramatic enough to warrant increased use. Airframe and aircraft-engine manufacturers are going to be using more and more of them,” he said. Specifically, he cited increased demand from large-scale production firms, such as General Electric, Pratt & Whitney and Rolls-Royce.

In anticipation of this, makers of tools for turning operations have redesigned their products. Geometries, for example, have been tailored to be more application-specific.

In the cutting zone, a tool’s edge geometry is critical for shearing chips cleanly. Generally speaking, for titanium and nickel-base alloys, this means maintaining a 10°-positive-rake angle on the insert to avoid plowing the workpiece and causing catastrophic tool failure.

“In many cases, positive action gives you a freer action, because nickel-base and titanium materials are difficult to cut,” said Tally Persichetti, product manager for Kennametal Inc., Latrobe, Pa. Lathe operators want to keep that action free, he added, because they don’t want to generate too much heat. In the case of titanium, ignition of the workpiece is possible.

In addition to higher positive top geometries, tool designers have developed inserts with smaller hones, or less edge rounding, for machining these materials, said Chuck Schneider, product manager for Walter Waukesha (Wis.) Inc. By adding these features, toolmakers create inserts that are material-specific.

But because such features also make the tools more brittle, the substrate must offer a healthy combination of toughness and hardness. This, as we will see, is exactly the direction tool-material research is heading.

Today, in recognition of the expanded market for turning difficult-to-machine materials, Waukesha has developed geometries for finishing, medium finishing and roughing high-temperature alloys. Conveying the seriousness with which his company is pursuing this market, Schneider said, “We now have 15 different grade/geometry combinations, whereas 2 years ago we had one.”

Walter Waukesha

Waukesha’s inserts for turning basic steel (left) and high-temperature alloys and stainless steels (right) are almost identical in terms of geometry. However, their substrates have been specially tailored for the materials they cut, a relatively new phenomenon. In addition, the edge preparation for the high-temperature cutter is much sharper, as indicated by the sharper point definition.

Naturally, chip control is another prime area of concern for tool designers. Because titanium and high-temperature alloys vigorously resist shearing, they require an insert that can tolerate rapid increases and decreases in cutting forces. “Within a period of milliseconds, the pressures build up to tremendous amounts and then drop right off to next to nothing, repeatedly,” said Schneider.

To illustrate his point, he detailed the chip-formation process for turning titanium. “At an average feed of 0.010 to 0.012 ipr and a depth of cut of 0.060" to 0.080", a machinist can ordinarily expect to see about that same thickness of chip coming off the work, per revolution. However, for titanium, that chip thickness is about 0.003" at the start of the cut, and it gradually increases to a point where the chip is practically 0.100" thick,” he said.

Insert edges, said Schneider, must be hard enough to cut the workpiece and tough enough to withstand the repeated, escalating shocks that come with these materials. Therefore, when designing inserts for these materials, Schneider said toolmakers must maintain insert sharpness by making hones as small as possible, as well as keep the surface as lubricious as possible, regardless of what coating, if any, is involved.

This, of course, does not mean that chip control is the sole province of a tool’s geometry and the cutting surface when turning exotics. For example, Carboloy’s Graham recommended high machine speeds as an effective means of chip management. “One thing that is not well known is that superalloys exhibit a strain-rate effect, meaning that these materials tend to behave in a brittle fashion if forced to move quickly.” He compared this to picking up a stick and snapping it over your knee quickly, rather than bending it slowly. The quick motion makes the stick brittle and easier to break.

Similarly, if the chip can be forced to bend quickly by cutting at high speeds, it will break more cleanly. For example,

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when machining Inconel 718 at 150 sfm, it's likely that long, unmanageable chips will be produced. But if that same material is cut at 300 sfm, the chips are much smaller, forming the classic "6" and "9" shapes. At the very least, the chips would be shaped like little springs, about ½" long.

Substrate Support

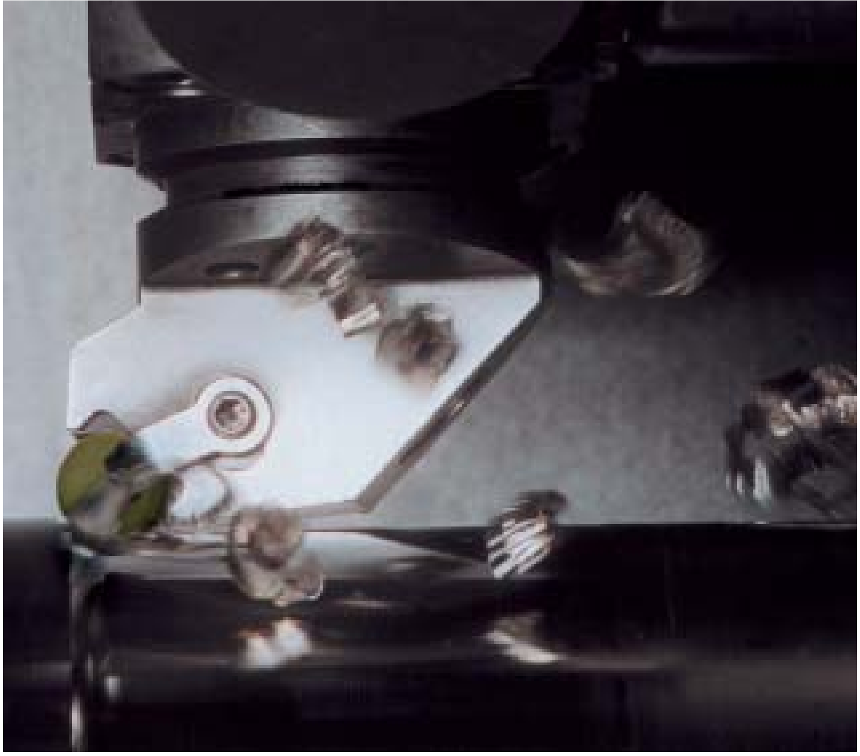
The insert's substrate is a significant factor when turning exotics. It must be tough enough to withstand the material's shear resistance.

To that end, micrograin carbide has greatly increased the edge toughness of inserts, allowing for the more positive rake angles and the smaller hones needed to machine exotics.

Schneider said Waukesha increasingly offers micrograin-carbide substrates for its customers who turn exotic materials. "We're finding that micrograin technology is more successful when machining high-temperature alloys because of the cutting forces involved."

Ceramics, too, according to Kennametal's Persichetti, are increasingly coming up big in regard to machining high-temperature alloys, especially those cut on newer, high-speed machine tools.

Meanwhile, Carboloy is experimenting with polycrystalline cubic boron nitride for machining superalloys, such as nickel-base and cobalt materials.



Kennametal

Kennametal's Kyron 1540 is a ceramic grade for machining high-temperature alloys.

Conceding that such machining is "not an easy application for PCBN" (and it's downright unsuitable for machining titanium), Graham boasted that during tests Carboloy has achieved speeds of 1,000 sfm on Inconel 718 and longer tool life than comparable ceramic inserts.

Are You in Good Hands?

Getting hold of the right substrate and edge geometry is all well and good, but the tool itself is useless unless it's in competent hands. Naturally, when a shop begins machining exotics, lessons are invariably learned and its knowledge base expanded. But how does this knowledge get out of one shop's door and into another?

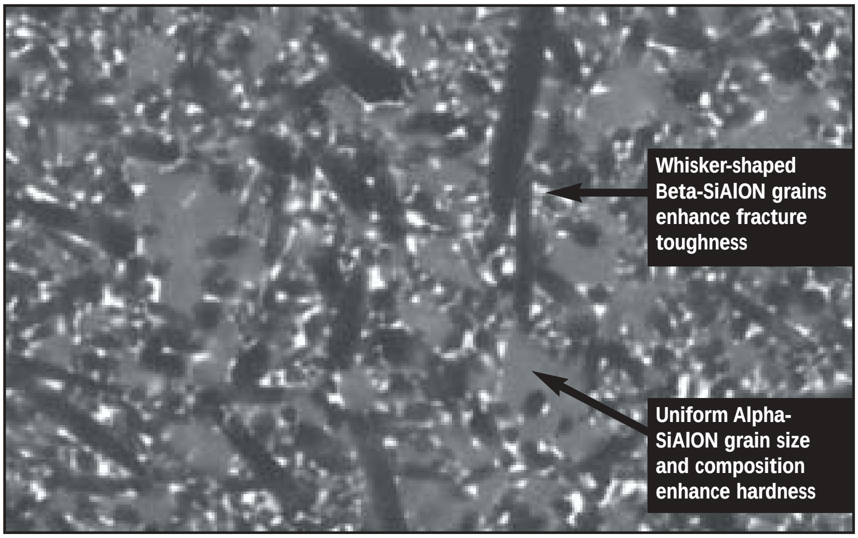
Schneider said the onus is on tool manufacturers.

One way Schneider is getting shops better acquainted with the tools for machining exotics is by encouraging the use of his company's tougher carbide grades. As the shop builds confidence in its technique, Schneider gradually increases the speed to the point where he can introduce grades that are harder and more wear-resistant and, despite being more brittle, offer higher productivity at the end of the day.

"We get a lot of smiles when we tell people that they can run these high-temperature alloys at 600 to 800 sfm and higher with some of the grades that we have, as well as those of our competitors," said Schneider.

But the job of learning how to machine exotics is not the tool manufacturers' alone. End users must be willing to learn new tricks and shop supervisors ought to encourage their employees to learn what they're cutting. Too often, Schneider said, "they simply give them inserts and jobs to run, and away they go."

For example, he said that one of the



Kennametal

This photograph illustrates the whisker-shaped Beta-SiAlON grains and the uniform Alpha-SiAlON grains that Kennametal says enhances the ceramic's hardness.

biggest causes of rapid tool failure when turning exotics is a misapplied grade. Schneider said such shops get a hold of an advanced carbide grade but don't ramp up speeds or feeds to match the substrate's and coating's potential.

"They're thinking in the 50- to 150-sfm range, so they're running high-technology inserts, grades and substrates at old-technology parameters, which leads to built-up edge. They're facing a big problem right from the get go," he said.

One technique employed by Schneider when troubleshooting exotics is to watch the insert on the first pass and examine the cutting edge immediately. If the cutting conditions are correct, there won't be BUE. If, however, the machine is running too slowly, BUE will occur within seconds during the first cut. If BUE is present, then he increases the speed by 10 percent per pass until it stops.

Although great strides in turning exotics have been made, toolmakers concede that much more needs to be done. "Speaking for the cutting tool industry," said Carboloy's Graham, "we have not done for the superalloy machinist what we have done for the steel and cast iron machinist. That's not for lack of trying; it's just testimony to the difficulty of machining these materials."

Difficult-to-machine materials need not be scary materials, though. And it's an open question whether to classify these materials as truly "exotic" anymore. Schneider, for one, didn't seem to believe the label fit. "There's a greater fear of these materials than really needs to exist. When properly applied, the geometries and carbide grades on the market make the machining of high-temperature alloys or titanium a piece-of-cake operation," he said.