Metalworking

# Tools and Tips to Tackle Inconel Machining—And Come Out on Top

Kip Hanson | Jul 11, 2023

**Inconel isn't the *most* difficult metal to machine, but it definitely earns a high ranking on the list.**

A blend of chromium, nickel, iron, molybdenum and other alloying elements, Inconel in all its grades is tough, hard and corrosion-resistant, with a melting point that makes it suitable for everything from gas turbine blades to nuclear reactor components.

But that said, it's just another metal: Given the correct speeds and feeds, modern toolpaths and a scientific approach to tool-life optimization, the Inconel family of heat-resistant superalloys (HRSA)—including Inconel 625, Inconel 718 and Inconel X-750—is quite machinable.

## Accurate Application of Cutting Tools

Choosing the proper tool coating is a great place to start when working with the common but often misunderstood metal, says Danny Davis, senior staff engineer for Solutions Engineering Americas at Kennametal.

"We're addressing Inconels from multiple angles," he says. One is the company's new coating, KCSM15A. It's "performing remarkably well in these and other high-temperature alloys—in many cases, we're seeing a 20 percent to 40 percent improvement in tool life."

How the cutters are applied is just as vital as the grade itself, adds Davis, but the exact approach depends heavily on the part geometry, material removal requirement and the type of machine tool.

"For example, shallow features and deep pockets require different strategies, so it's hard to offer specific advice without seeing the application," he says. "But as a general rule, anytime you're cutting depths two to three times the tool diameter, a high-efficiency or dynamic toolpath is the first choice."

The ***HARVI III*** and the ***KOR6 DT*** end mills are great options for that, he adds.

The advanced milling techniques feature gentle entries and exits, reducing shock, and provide maximum utilization of the cutter's length, he explains.

“In addition, the lower radial engagement (AE) and higher axial depth of cut (AP) allow us to incorporate a higher flute count,” he says. “If the application is rigid enough, we can use our high-density end mill RSM II. This cutter can have as many as 19 cutting edges and works great in high-efficiency machining (HEM) applications. This combination enhances our material removal rate while also leveraging chip thinning, which supports increased cutting speeds.”

For shallower cuts, Davis points to the company’s Harvey 1 TE solid carbide end mill as particularly effective—he notes that during a recent customer visit, experts machined pockets using a 95 percent stepover and achieved up to two hours of tool life.

## Cutting Inconel ‘Like Butter’

Jay Ball of Seco Tools has similar success stories to tell. The product manager for solid milling products in North America, he says more and more customers are adopting solid carbide as the cutting tool of choice for Inconel and heat-resistant superalloys in general.

“It might seem surprising to some, but we’ve had a lot of success with our hard milling geometries,” he says. “One example of this is our Niagara Cutter MZN410R four-flute high-feed end mill that was designed specifically for hardened steel. We applied a silicon coating to it and saw an immediate 50-plus percent increase in tool life. It plows through Inconel 718 like butter.”

As with the tools from Kennametal and others, the new coating grades get the credit for such advances.

“It started seeing heavy use in the hard milling and mold-making industries, which for a long time, predominantly used aluminum titanium nitride (AlTiN) products,” Ball says. “However, we began incorporating silicon into our coatings to enhance wear-resistance and combat abrasiveness. As it turns out, these tools also work extremely well on Inconel and Hastelloy, typically increasing tool life by 20 percent to 30 percent on average.”

The carbide substrate plays a role as well. Ball explains that cutting tool manufacturers like to use a higher cobalt percentage in difficult materials like Inconel, where chipping can be a significant issue due to workholding, fixturing and similar factors.

But a higher cobalt percentage—resulting in a tougher end mill—often comes at the cost of wear resistance. “That’s where the addition of a silicon coating becomes beneficial, as it helps to enhance the tool’s wear resistance, thereby balancing out the two properties,” Ball says.

Seco’s knowledge of those benefits inspired the Niagara Cutter HTA range of solid carbide end mills dedicated to machining heat-resistant superalloys, he adds.

## Keep Current on Machine Tool Technology

For manufacturers working with challenging materials, staying abreast of ***advances in cutting tool technology*** and toolpaths is critical, says William Durow manager of the Global Engineering Project Office for Sandvik Coromant US.

It’s not like the 883- and 905-carbide days, where a single, all-purpose grade served as a decadeslong go-to for many shops.

Sandvik Coromant and most of its competitors continually invest heavily in developing new coatings, grades and ***geometries***, and the shops trying to maximize productivity—regardless of what they’re machining—embrace those products.

Bringing them to market isn't always easy, though.

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> William Durow
> Sandvik Coromant US

New materials and techniques "are often met with hesitation from original equipment makers and suppliers," Durow says. "This is primarily due to the extensive testing and paperwork required to ensure safety and efficiency. After all, the stakes are incredibly high—any failure, particularly in aerospace, can have devastating consequences."

Much of the concern centers around the finished surface and the toolpaths used to generate it, so there's generally more leeway on strategies or cutting tools for roughing operations.

Such parameters typically indicate a "light and fast" strategy when machining Inconels.

The superalloys are "designed to resist heat," Durow says. "And as we stress in our customer-training sessions, the heat generated during machining should be transferred to the chip, not the tool or the workpiece. Unfortunately, heat-resistant materials tend to do the latter."

Durow offers an everyday example: taking a 2-inch-wide cut with a 2-inch-diameter cutter.

"This is a significant area for heat propagation, potentially leading to faster tool wear or even damage to the workpiece," he notes. "Lighter radial engagements utilizing high-feed, high-efficiency toolpaths that leverage the chip-thinning effect are almost always the best choice in these metals."

## Drilling Inconel—and Beyond

Drilling comes with its own technical challenges.

Inconel alloys aren't much harder to drill than materials such as austenitic stainless steel, titanium and some alloy steels, says Guhring Inc.'s Brandon Hull, vice president of product management and business development. But like any material containing high amounts of nickel and chrome—they do tend to work-harden, so pecking should be avoided at all costs.

Doing that requires a ***coolant-through tool***.

"I wouldn't undertake any drilling operations in Inconel without using a coolant-fed drill, preferably one with at least 500-psi high-pressure coolant behind it," Hull says. "In fact, if I were operating a machine shop, I might be hesitant to accept jobs with high numbers of holes if I didn't have coolant-through-the-spindle capability. It's almost essential when you're machining Inconel, especially for deep-hole drilling."

Hull makes a similar recommendation for milling, especially in operations such as pocketing and slotting, where high-pressure, coolant-fed tools blast chips away and reduce the possibility of recutting.

He also concurs with his counterparts regarding toolpaths.

"The key principles I would apply when milling Inconel are the use of high-speed milling techniques that involve taking deeper depths of cut, utilizing the full cutting edge on the end mill, opting for a lighter width of cut and using multi-fluted tools—something in the neighborhood of five to 10 flutes," he says. "This approach allows you to gently peel the material away, as opposed to aggressively hogging it out."

To accomplish that, Hull recommends the company's RF 100 "Speed" family of end mills, which are available in five-flute (5-Speed) and seven-flute (7-Speed) as well as various lengths and coating options.

"These tools have a medium to high rake angle—around nine degrees—which can accommodate chip splitters for reduced side-loading in the longer lengths," Hull says. "Another key feature of these tools is their stepped core design. They have a more open flute geometry at the end that aids in chip formation and evacuation with shallower depths of cut. If you're using the full length of the tool for side milling and high-speed milling, the core steps up and becomes bigger, providing additional strength for deeper depths of cut. Overall, that would be our top recommendation for milling operations in Inconel."

 