



Machining

Cutting Titanium and HRSA Metals: Machinability, Coolants and Beyond

Don Sears | Dec 05, 2018

Metals such as heat-resistant superalloys and titanium can be really difficult, but with the right approach and guidance in machining, tool holding and insert selection, machine operators can overcome the problem areas.

From implantable joints in the human body to big parts for marine facilities in the oil industry to engine turbines in aerospace, heat-resistant superalloys and other alloys are being used regularly across major manufacturing segments. But they can be arduous to machine.

If the goal is to make parts at the highest quality in the least amount of time, then having an understanding of the kind of tooling to use is essential. No one wants to burn through tools or cause production delays because of super dense, hard metals that rev up the machine but cut super slow or inaccurately. Having an understanding of a machine's capabilities is essential too—as is knowing the tools that will work the best for the tough materials.

“The primary application for HRSAs is hot zone turbine components for both aircraft and power generation—parts like blades, blisks, brackets, valves, and manifolds, most of which are complex and contoured,” writes Ed Sinkora for Advanced Manufacturing in the *article* “Hot Techniques for Cutting High-Temperature Alloys.”

“That means using 5-axis milling to achieve the required forms and tolerances in one clamping. And for smaller parts, *solid-carbide round tools* are needed, requiring particularly stiff tool holders,” explains Sinkora.

Many industries are under manufacturing pressure. The time it takes to achieve quality parts really matters, especially in very competitive markets.

“The main focus is on process reliability since these structural components are extremely expensive,” notes Walter Tools in an article about pocket milling titanium in aerospace. “At the same time, cost pressure from the market demands high machining and productivity performance.”

To get to that comfortable level of “process reliability,” there is a lot of know-how with using the right machines, workholding, tooling, toolpaths and coolant—all together—find machining and tooling professionals. We explore the top tooling and machining guidance for titanium, HRSAs and alloys.

Know the Metal's Machinability Rating

If cutting titanium, stainless steel or HRSAs, it is likely many of the parts being made will have nickel or chromium—and sometimes cobalt—in them. Common nickel-alloys include Inconel, Waspaloy, Hastelloy, stainless steels including 304, 316 and 17-4, and others.

"[Nickel is] tough, corrosion-resistant and exhibits excellent strength and impact properties," notes Kip Hanson, a manufacturing consultant, in the article "[*5 Metal-Cutting Tips for Nickel-Based High-Temp Alloys.*](#)"

"Given a sharp tool and the right cutting parameters, pure nickel is not terribly difficult to turn or mill, although nickel alloys such as Ni-Span-C 902 and Monel K-500 bear machinability ratings of 15 percent or less," Hanson explains.

And machinability is the whole point. Luckily, many of today's machines and cutting tools can handle most materials—but the challenge is to know the right tools and techniques for creating a repeatable and timely machining process. To that end, it helps to understand how a material is rated, so using a *machinability rating chart* can help.

But nothing can replace real-world experience and knowledge: Talk about machinability issues with the people who are doing it today. Join the metalworking forum [registration required].

In many cases, it also helps to use the technical guides provided by tooling suppliers, such as this one from Sandvik Coromant:

"Application Guide: Heat Resistant Superalloys"

In this guide, **Sandvik Coromant** has this to say about HRSAs: "The physical properties and machining behavior of each [alloy group] varies considerably, due both to the chemical nature of the alloy and the precise metallurgical processing it receives during manufacture. Whether the metal is annealed or aged is particularly influential on the subsequent machining properties."

Want to know more about the makeup of materials you use? Read "A Cutting Tool Selection Guide: Ferrous vs. Nonferrous Metals."

Watch the Heat, Use Metalworking Coolants

The heat generated in a CNC machine on the surface of the material at the speeds and feeds needed to make accurate, reliable cuts with the proper chips is hard to understate. It can be a real challenge to inserts and tools.

"Poor heat conductivity and high hardness generate high temperatures during machining," notes Sandvik Coromant in the article "[*Selecting the Right Turning Insert for HRSA Materials.*](#)" "The high strength, work hardening and adhesion hardening properties create notch wear at maximum depth of cut and an extremely abrasive environment for the cutting edge."

How should a machinist protect against this? For many applications, use carbide-based cutting inserts that keep the edge tough and adhere to the substrate and help avoid deformation.

"In general, use inserts with a large entering angle (round inserts) and select a positive insert geometry. In turning and milling, ceramic grades can be used, depending on the application," explains Sandvik Coromant.

And don't forget the role of coatings and coolant, advises Scott Etling, a product management director at Kennametal, in the article "*The Heat Is On Difficult-to-Machine Metals.*"

"You have to have the right PVD coating, a tough substrate, the right geometry, right edge prep, and high shear geometries," says Etling. "The heat doesn't go into the chip like it does in steel. The heat has to go somewhere, so for most titanium applications you have to use an enormous amount of coolant."

For more on coolant and HRSA, read Sandvik Coromant's *application guide*. The tooling maker suggests the following:

"Coolant should be applied in all operations excluding milling with ceramics. The volume should be high and well directed. High pressure coolant HPC (up to 1160 psi) shows positive results in terms of tool life and consistency."

Keep the Workpiece Rigid

"Machining HRSA requires a very stable machine, rigid workholding and a very stiff interface between spindle and toolholder," notes Sinkora.

There is much more to know than simply the material and the cutting tool. There are also the necessary elements that help keep a workpiece in place and at a balanced strength that can withstand the very high rpms and throughput today's machines and innovative cutting tools can handle.

"Machining of titanium and other heat-resistant superalloys generate high cutting forces not only in the radial direction, but also in the axial direction, which can result in tool pull out," says Hanson in the article "Lessons in High-Performance Machining: Don't Forget the Tool Holders." "It is even more important to use the right type of *tool holders* to prevent tool failure and part scrap. It might not be much—maybe just a few thousandths of an inch at a time, but chances are good that it's enough to scrap out some very expensive parts."

If using side-lock holders, it may be time to bring in something new and improved. Many vendors license Haimer's patented Safe-Lock technology. But it isn't only about increasing the tool life from reducing pull out. It's also about reducing chatter and harmonics—and not damaging a machine's spindle—so hydraulic chucks in HRSA part making are worthy of evaluation, as are making sure the CNC has HSK, Capto, KM4X or other technology.

"When you're running machine tools that fast, usually over 12,000 rpms, it's recommended to always balance the complete system, (i.e., toolholder with the cutting tool)," says Ronald West, senior global product manager at Kennametal in the tool holder article. "It just increases tool life and decreases spindle wear ... It's a little more difficult with a collet chuck or end mill adapter to maintain balance due to their design and required hardware, but typically hydraulic chucks and shrink fit adapters are much easier to fine balance for high speed applications."

To Rough HRSA, Try Ceramic Tools; Keep Toolpaths Long

"*Ceramic cutting materials* offer excellent productivity in roughing operations in FSM and ISM. Their application differs greatly compared to carbide ..." notes Sandvik Coromant in its application guide for working with HRSA. The reason for that is ceramics allow for high cutting speeds that help produce a "highly plasticized and sheared chip."

The key to roughing HRSA is in the speeds and feeds so you can get to the right temperature, according to experts. Speeds of over 3,000 surface feet per minute are recommended.

"[T]he first step is setting the right speed to raise the temperature in the cutting zone to create a certain degree of plasticization of the material, making it easier to machine," **says** Jan Andersson, global manager at Greenleaf Corp. "Otherwise, you struggle with unpredictable tool life. After determining the appropriate speed, you use feed rate to manage thermal evacuation. The higher the feed rate, the more mass in the chip. The more mass in the chip, the more heat you transport away from the cutting zone. That controls the chemical wear component."

Another key point: Toolpaths need to stay as long in the cut as possible to keep your tools alive and useful as long as possible. It means employing proper programming in your CAM to force radius in every toolpath.

"The key programming technique we look for in Inconel and other superalloys is keeping the tool in the cut as long as you can," says Dale Mickelson, product manager at Methods Machine Tools in an Advanced Manufacturing **article**. "Because every time you enter and exit the cut you lose tool life. So we create pocketing routines that move down into the part helically. If you have a flat, you cut down to that flat helically and then finish the flat surface."

Need advice from other experienced machinists and metalworking specialists? Jump in on the conversations over at the metalworking forum [registration required].

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