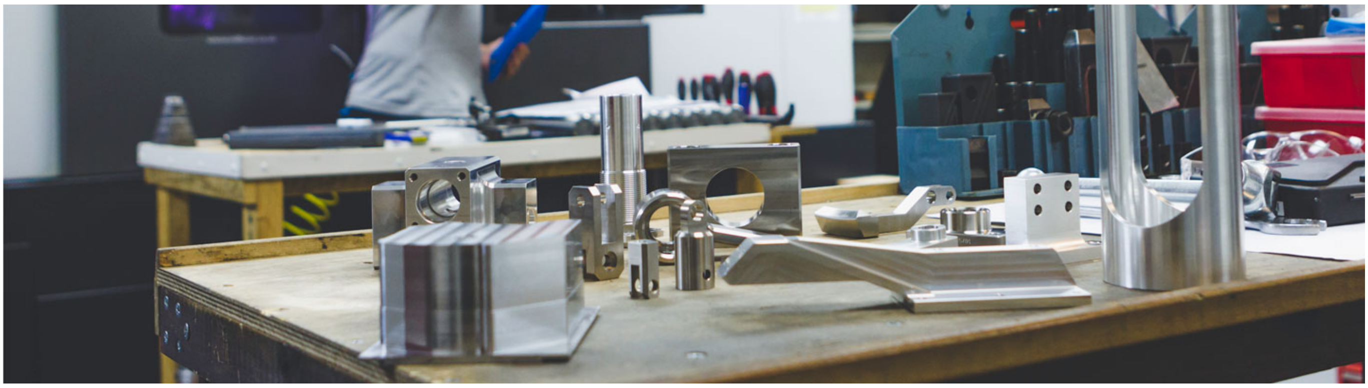

Machining

5 Metal-Cutting Tips for Nickel-Based High-Temp Alloys

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What You Need to Know

Nickel and its various alloys tend to work harden during machining. To combat this, the cutting tool should have a positive rake and sharp edge.
Making setups as rigid as possible is especially important for super-tough metals like nickel and nickel-bearing alloys.
All cutting tool manufacturers supply recommended surface speeds, depths of cut and feed rate ranges. When trouble strikes, shoot for the upper end of those parameters and cut more aggressively, not less.
Proper programming strategies are paramount. Trochoidal toolpaths provide consistent chip loads and prevent shock to the cutting tool and workpiece alike.

Nickel and its alloy cousins are tough to cut, but nickel's corrosion resistance and strength make it ideal for so many applications, including in aerospace and other key manufacturing industries. Get clear, concise advice on how to work with this vital material—and how to get the most out of your cutting tools.

As number 28 on the periodic table, nickel was first isolated in 1751. Its name comes from the belief by German miners that the reddish-brown metal, known then as "kupfernickel" (which translates to "devil's copper") was making them sick. In reality, their illness was caused by the high amount of arsenic contained in the ore they were removing from the cobalt mines of Sweden.

Nickel is an extremely important metal. Along with chromium, it is one of the most essential of all alloying elements, used in a wide variety of steels, stainless steels and superalloys. It's tough, corrosion-resistant and exhibits excellent strength and impact properties. Common types of nickel-alloys include Inconel, Hastelloy, Waspaloy, stainless steels including 304, 316 and 17-4—and others. 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. Here are a few things you should know if you're currently working with, or about to work with, this challenging material.

1. Keep Your Metal Cutting Tools for Nickel Alloys Coated and Sharp

Nickel and its various alloys tend to work harden during machining. There are several ways to combat this. First, the cutting tool should have a positive rake and sharp edge. Because it is less brittle than carbide, high-speed steel might work well, although the cutting speeds in this case must be kept quite low, typically at 100 surface feet per minute or less as a starting point.

Depending on the alloy, a tough, premium grade ***PVD-coated carbide*** will generally provide the best tool life and productivity, although some cutting tool suppliers suggest ceramic or cermet as an alternative—be open to their recommendations. CBN may be used on hardened 17-4 PH and similar heat-treated alloys. Use a round insert or one with a positive lead angle wherever possible to minimize notching. ***Variable helix and variable flute end mills*** help to break up the harmonics that lead to chatter. If using HSS, drills should have a sharp chisel edge and a split, 135-degree point. Keep tools sharp and replace them sooner rather than later before disaster strikes.

2. Stay Rigid in Your Nickel Alloy Cutting

Making setups as rigid as possible is good advice for any machining application, but especially so for super-tough metals like nickel and nickel-bearing alloys. For milling operations, a ***shrink-fit holder*** is often the first choice, with hydraulic or mechanical milling chucks coming in a close second. Leave the sidelock holders in the tool crib. Similarly, hydraulic ***work holding*** should be used whenever possible, even if it means investing in new vises and chucks. Overhangs must be kept to a minimum to avoid tool deflection and the chatter that comes with it. This might be a good time to investigate vibration-dampening boring tools, and if your machine tool is so equipped, be sure to understand and engage its anti-chatter functions.

Want to learn more about high-temperature metals used in aviation industries? Read "4 Aerospace Materials That Are Taking Off."

Cutting Fluids: Neat Oils Can Work Well with Nickel, But Not with Ceramic Tools

You might have put sulfur-based cutting oils out to pasture when the shop's last screw machine was retired. Who can blame you? They're smelly, smoky and many modern machine tools are not designed for them. That said, so-called neat oils are often an excellent solution for machining nickel and nickel-based alloys. Although not as effective at removing heat from the cutting zone as water-soluble and synthetic cutting fluids, they're generally much more lubricious. Better yet, some oil manufacturers offer vegetable-based cutting oils that are far friendlier to humans and the environment, and do a good job on nickel and other difficult materials.

Beware of oil, however, when using ceramic cutting tools. Their high cutting speeds (think red-hot) may lead to a fire, especially where any amount of oil mist is present. Want to avoid oils altogether? Look for a high-quality water-soluble cutting fluid designed specifically for superalloys, one high in extreme pressure (EP) compounds such as sulfur and chlorine (the same stuff that makes oil so effective). And if you have high-pressure coolant capabilities, now's the time to use them.

3. To Aid Tool Life, Get Aggressive with Feeds and Speeds

Having trouble with tool life? Your first instinct might be to ease off on the feed and slow down the spindle. Bad idea. All cutting tool manufacturers supply recommended surface speeds, depths of cut and feed rate ranges. When trouble strikes, it's often a good idea to shoot for the upper end of those parameters and cut more aggressively, not less. Doing so, however, first depends on the points just mentioned—a rigid setup—as well as using the correct grade of cutting tool. Above all, learn to identify failure modes—notching at the depth of cut line and built-up edge (BUE) are common with nickel-based materials, both of which lead to catastrophic tool failure if not addressed in a timely manner.

4. Take the Right Toolpath

Proper programming strategies are paramount. Trochoidal toolpaths provide consistent chip loads and prevent shock to the cutting tool and workpiece alike. Because nickel-based alloys are tough, stepovers should be well below the radius of the milling tool and feed rates relatively high. Conversely, the minimum depth of cut for turning should be no less than the tool nose radius, and preferably several times that if possible. High feed milling techniques using button-style and comparable cutting tool geometries drive forces upward into the spindle, minimizing deflection. Ramping into and out of the cut is effective on both CNC lathes and machining centers. Avoid dwelling in corners.

5. Find the 'Goldilocks' Zone: Document Your Parameters and Cutting Conditions

Finding the sweet spot for machining alloys high in nickel requires some trial and error. You can avoid unexpected failures by developing a predictable, tested process, but this in turn calls for documenting what tools, grades, coatings and cutting parameters have been tried, and the results for each. Take baby steps. Don't be afraid to push beyond the manufacturer's recommendations, but be sure the process is stable before walking away from the machine. If you have it, use your machine tool or tool crib's tool life management function to monitor how long a tool has been in the cut—if not, document tool life the old-fashioned way, using pen and paper. If you can get 15 minutes out of an insert, count yourself fortunate. Nickel machining is no time for tribal knowledge, second-shift secrets, or uncontrolled process changes. Get documenting.

What kinds of issues or problems have you encountered when cutting nickel or its alloys? Share your experience.

