



Machining

IMTS 2018: Advanced Grinding Wheels in Aerospace

Kip Hanson | Aug 06, 2018

Get a deeper understanding of how to best grind superalloy materials. If you're attending IMTS this year, take note of the multiple conference sessions focused on high-performance grinding—and see techniques that will help you in your everyday machining operations.

Used widely in the aerospace and energy sectors, metals such as Inconel 718, Hastelloy C-276, and Monel K500 are both temperature- and corrosion-resistant, with mechanical properties far superior to their wimpy steel cousins.

“Nickel-based superalloys, which constitute greater than 40 percent of the total weight of an aircraft engine, find applications in the combustor and turbine sections of the engine,” *notes* Dr. K. Philip Varghese, group leader of advanced application engineering at Norton | Saint Gobain, in an IMTS 2018 conference presentation description. “Their use is primarily on account of the unique combination of high temperature strength, toughness and resistance to degradation in extreme environment.” Varghese is presenting “High-Performance Grinding of Nickel-Based Superalloys” on Wednesday, Sept. 12, at 10 a.m. at IMTS in Chicago.

Unfortunately, these superalloys are also quite challenging to grind. Work hardening is common due to the high pressures involved, and the poor thermal conductivity of most superalloys means heat within the grinding zone is high, possibly damaging the workpiece if left unchecked. This can also mean that workpieces must be allowed to cool and “de-stress” between roughing and finishing operations.

Where B1112 steel has a machinability rating of 100 percent, most Inconels come in at 12 percent, and the high cobalt L-605 (aka Haynes 25) ranks at just 9 percent machinability. Adding insult to injury, grinding is typically one of the last processes performed on a workpiece. Customer delivery dates can easily slip in the event of scrapped parts or other production delays. Whether surface, cylindrical or centerless grinding, working with these super-materials can be daunting.



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Alternative to Traditional Grinding: Multitasking Machines

Sometimes the best way to grind a superalloy part is to embrace new technology. Imagine a machine that lets you rough and finish turn an Inconel shaft or titanium rotor, mill some pockets, and then grind a bearing journal, gear form or complex internal detail on that same part to within a micron without it ever leaving the machine. Thanks to a new breed of CNC equipment, this manufacturing fantasy is now a reality.

They're called multitasking machines. One step beyond a mill-turn center, multitaskers combine turning, milling, grinding, gear-hobbing, laser-cutting and even additive manufacturing processes in the same operation. Most are equipped with tool changers and large tool magazines, allowing multiple jobs to be set up and ready at a moment's notice. Turn mill machines use CBN turning inserts as opposed to grinding wheels in order to achieve the objective. Fixture and handling costs are reduced, throughput and part quality are improved, and there's never a risk of scrapping out an expensive part on its final operation.

But if you are more comfortable with grinding and want to learn more about the newest grinding techniques and technologies out there, be sure to check out the following conference sessions at IMTS 2018:

Monday, Sept. 10:

"Advanced Grinding Takes Aerospace Parts to New Heights" by Larry Marchand, vice president at United Grinding

Wednesday, Sept. 12:

"High-Performance Grinding (HPG) of Nickel-Based Superalloys" by Dr. K. Philip Varghese, group leader of advanced application engineering, Norton | Saint-Gobain

Thursday, Sept. 13:

"Trueing of Diamond Grinding Wheels" by Dr. Jeffrey Badger, independent consultant, The Grinding Doc and Rob Robbins, sales manager, Rush Machinery

Grinding Wheel Types: Selecting the Right Wheel for Superalloys

Fortunately, there are a number of ways to become a high-performance grinding shop, starting with

a selection of the best grinding wheels. Many experts suggest that the parameters used to grind steel are equally applicable to superalloys. This in turn suggests that an aluminum oxide wheel—preferred for grinding carbon and alloy steels—is the first choice for superalloys. This is good advice, although most grinding wheel suppliers offer premium products specifically designed for nickel-based materials. These are generally a ceramic-alumina mix, which due to a friable but strong bond generate minimal heat and are largely self-sharpening.

“Only specific abrasive wheels that can remove stock at low threshold power/forces and consume lower specific energy in grinding of these superalloys, can survive the conflicting goals of higher productivity as well as higher wheel life in an HPG [high-performance grinding] process,” notes Varghese.

Because superalloys are gummy and tend to load the wheel, this is an important attribute. Also important is the need for an open grain, which helps to eliminate the heat buildup that leads to heat checking and microcracking. Worst case, a wheel that loads up and rubs the workpiece surface rather than cutting it can cause what’s known as a white layer, a big no-no in the aerospace world because it reduces the material’s surface integrity.

Of course, grinder wheel selection depends on many factors. Surface grinding operations behave differently than cylindrical grinding—and cylindrical grinding behaves differently than creep feed or centerless grinding. The actual superalloy being machined and the amount of material removal plays a role as well—where a vitrified CBN wheel might work best for rough grinding a beveled gear form in titanium, creep feed grinding the root form on an Inconel turbine blade often calls for an advanced ceramic.

The Role of Coolant and Cutting Fluids in High-Performance Machine Grinding

Just as an open grain, friable wheel is a good place to start when grinding superalloys, so too is a high-quality, well-filtered and maintained **water-soluble cutting fluid**, preferably one with sulfur and/or chlorine additives to provide lubricity. This will assure maximum material removal without the risk of heat-induced surface damage. That said, be sure to check with your customer on the use of sulfur and chlorine-based cutting fluids, as some aerospace companies restrict their use due to the possibility of intragranular corrosion.

In the case of **CBN wheels**, however, or where the customer prohibits the use of certain water-soluble oils, a straight oil should be used, although this is admittedly not as effective at removing heat as is a water-based coolant. Whatever the fluid, its velocity should exceed that of the wheel speed as measured at the workpiece surface. And if grinding a special form, the nozzle shape should match that form so as to provide 100 percent coverage. Finally, because grinding tends to break fluids up into microscopic particles, and because these particles can be carcinogenic, always use a properly sized air filtration system for operator safety.

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Group Leader, Advanced Application Engineering, Norton | Saint Gobain

Pick the Right Supportive Grinder Wheel Dresser

Since superalloys push the limits of any grinding process, the window of wheel effectiveness is often

quite small. It may therefore be necessary to change them in-process, as the bond, grit and hardness used for roughing will possibly be completely useless for precision finishing. As any grinding machine operator knows, grinder wheel changes are a fact of life, but for production purposes a machine with automatic wheel-changing capabilities will bring you a big step closer to optimal throughput.

Another big step is *continuous wheel dressing*. Aftermarket attachments exist, although ordering this option on your next CNC grinder is probably the best bet, budget permitting. For the same reasons that open grain, self-sharpening wheels are most effective with superalloys, continuous dressing leaves the wheel sharp at all times. Grinding forces are reduced, surface finish and accuracy are improved, and there's little concern over creating white layers or other types of surface damage to a critical aerospace, nuclear or medical component.

If your current grinder wheel is in its teens or older and you have the workload to support it, invest in a modern CNC grinder designed specifically for demanding aerospace work. With features like auto-dressing, integrated part measuring, pallet changing and robotic part handling—and advanced, multi-axis motion control, today's machine tools are well worth the investment. If you want to be a high-performance grinding shop, this might be the perfect place to start.

Have you overcome the common problems in grinding superalloys? Share your stories.

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