Aerospace

Ceramic End Mills Help Optimize Aerospace Part Machining

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Up to 30 times more speed in HRSA materials with ceramic end mills

CM316

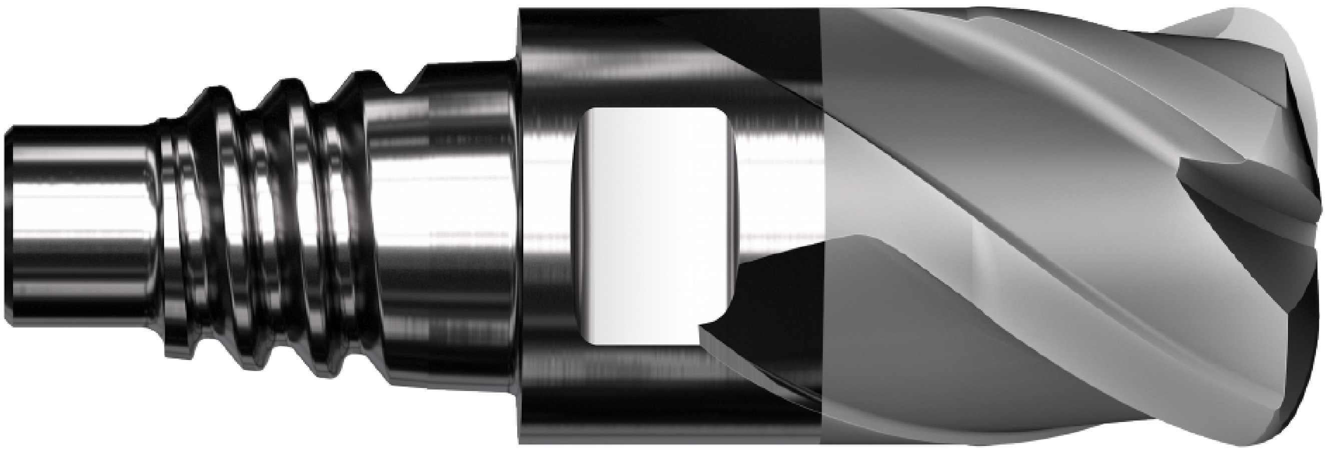
With components made from nickel-based alloys becoming increasingly prevalent across the aerospace industry, the demand for optimized cutting tools continues to grow. For common operations such as shoulder and face milling, the machining of nickel-based materials remains challenging. Although offering excellent performances, these materials exhibit poor machinability due to their low thermal conductivity, potential for adhering to cutting tools and the presence of abrasive particles within the alloy structure. Due to these issues, productivity with carbide tools tends to be low. In addition, part complexity means that some components demand extended reach, while process flexibility is another factor high on the wish list at many aerospace manufacturers. Here, new ceramic end mill technology has emerged to help meet these requirements, offering the potential to optimize the machining of aero-engine parts and provide significant competitive gain.

There are many challenges facing those tasked with producing aerospace engine components. Most such parts are manufactured from HRSAs/nickel-based alloys, which place a particular set of demands on production engineers looking to manufacture components like spools, turbine disks, combustion casings and blisks.

Up to 30 times more speed

Although many manufacturers use conventional solid-carbide end mills, such tools have their limitations in terms of performance when it comes to nickel-based alloys. In a highly competitive global arena, aerospace machine shops are looking for next-level technologies capable of delivering a step-change in factors such as productivity and/or tool life. Ceramic end mills can provide that very leap, offering up to 20-30 times more machining speed in comparison with solid-carbide tools for operations such as shoulder and face milling. Such impressive gains can be achieved largely because ceramic cutters retain their hardness at the high temperatures which arise when machining nickel-based alloys.

The latest offer from Sandvik Coromant in this area is the brazed ceramic ***CoroMill® 316*** exchangeable-head end mill for roughing operations. In the first instance, the exchangeable head concept facilitates inherent process flexibility. Available is a six-flute version with a straight corner radius that delivers highly productive side milling operations, and a four-flute version designed to boost face milling thanks to its high-feed face geometry.



CM316 Ceramic 4 Flute

The ceramic substrate of the latest ceramic end mills allows for a different cutting process in comparison with traditional solid-carbide tools. Importantly, the unique CC6060 SiAlON grade is purpose-designed for the superior machining of nickel alloys, and is supported by negative geometry that provides a tough cutting edge. The latter also features a T-land for stable operations.

SiAlON carries a chemical composition of aluminum oxide and silicon nitride (Al2O3 + Si3N4), a combination that promotes high wear resistance, even at elevated temperatures.

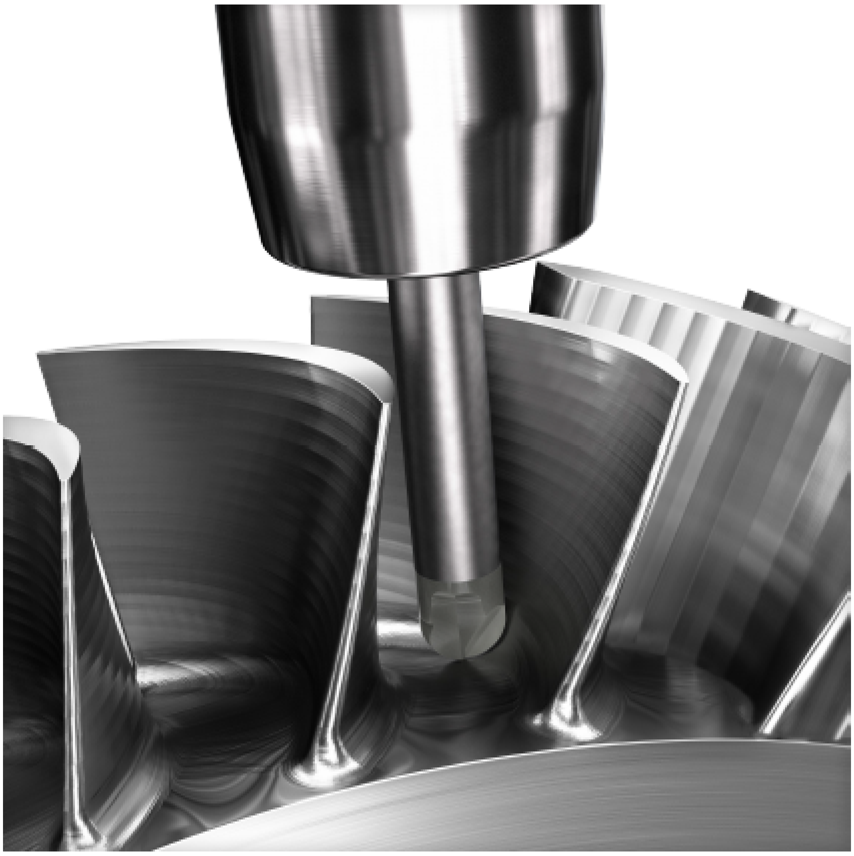
Stable machining

While the brazed ceramic **CoroMill 316** is best for difficult reachability applications, or to take advantage of exchangeable-head flexibility, Sandvik Coromant can also offer the ceramic **CoroMill Plura** end mill, for tasks where extra stability is pivotal to machining success.

In fact, a stable set-up is advised in all cases, and always without coolant application; machine shops should use pressurized air instead as coolant would simply burn at the high temperatures involved. In addition, the use of coolant promotes thermal shocks and has a negative effect on tool life. Importantly, high spindle speeds are required, of at least 13,000 rpm. Further recommendations include the use of down milling, as well as a programmed tool path that keeps the tool in constant contact with the material.

To highlight the potential gains on offer, consider a recent customer trial involving an aerospace stabilizer made from aged Inconel 718 (370 HB). The trial, which demanded slot milling using a 12mm diameter **CoroMill Plura** ceramic end mill, took place on a DMG 60 eVo vertical machining center.

By replacing the existing (competitor) solid-carbide end mill with the ceramic **CoroMill Plura**, the customer was able to increase many of the cutting parameters significantly. For instance, cutting speed was increased from 25 to 500 m/min (82 to 1640 ft/min), while feed speed could be elevated from 92.82 to 2387.34 mm/min (3.71 to 95.49 in/min). In addition, axial depth of cut was doubled, from 0.25 to 0.5 mm (0.01 to 0.02 in). The same 12 mm (0.472 in) radial depth of cut was deployed, while feed per tooth was in fact reduced slightly from 0.035 to 0.03 mm/z (0.0014 to 0.0012 in/z).



CM Plura Ceramic Blisk

The customer was highly impressed with the results. Metal removal rate (MRR) climbed from 0.28 to 14.32 cm^3/min (0.02 to 0.9 in^3/min), a remarkable gain of 5014%. In addition, tool life was extended by 300%.

Good chip evacuation

The large increase in cutting speed for this trial was significant. High cutting speed increases the cutting temperature, making the chips highly sheared. In fact, the process generates dust-like chips, which is good for chip evacuation using pressurized air.

Many additional trials have been conducted against competitor ceramic tooling. For instance, using identical cutting data, a 12 mm ceramic end mill from Sandvik Coromant was put to the test against three competitor cutters when face milling Inconel 718 (43 HRC). Machining parameters included 5 mm (0.197 in) radial depth of cut, 0.5 mm (0.02 in) axial depth of cut, 940 m/min (3084 ft/min) cutting speed and 0.12 mm/rev (0.0047 in/rev) feed rate. The Sandvik Coromant ceramic end mill completed a machining length of 90 m (295 ft), some 490% better than its nearest rival. In fact, upon visual inspection, some of the competitor cutters started exhibiting tool wear after just 3 m (9.84 ft) of machining length. *Watch the short video below to see the CoroMill® Plura and CoroMill® 316 in a high speed roughing application using HRSA.*

The results were equally impressive in side milling tests. Using the same material and cutter diameter, cutting tool data included: 5 mm (0.197 in) axial depth of cut; 0.5 mm (0.02 in) radial depth of cut; 600 m/min (1969 ft/min) cutting speed and 0.12 mm/rev (0.0047 in/rev) feed rate. Here, the Sandvik Coromant ceramic end mill outperformed the next-best cutter by 250%, completing a machining length of 16 m (52.5 ft) before requiring replacement.

No white layer

Of note, no white layer formation has been observed when using the latest ceramic end mills from Sandvik Coromant. Tests have been conducted for a wide range of cutting speeds between 375 and 900 m/min (1230 to 2953 ft/min) without any evidence of this unwanted effect. White layer, which is thought to encourage cracks, is associated with temperature created on the surface of a workpiece followed by quick cooling.

Beyond shoulder milling and face milling, the latest ceramic end mills can also be used for pocket milling, helical interpolation, ramping and slot milling. Both **CoroMill Plura** and **CoroMill 316** are part of the Sandvik Coromant Optimized Solutions offer within the company's Solid Round Tools range.

The newly introduced series also includes a ceramic ball-nose version of **CoroMill 316** for blisk machining. This profile-milling solution is suitable for both roughing and finishing operations.

*To learn more about the CoroMill Plura and the CoroMill 316, download the brochure **here**.*