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Milling Techniques to Improve Metal Removal Rate

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What You Need to Know

KCSM40 is a new milling grade that improves the thermal resistance of cutting-tool inserts used to machine high-temperature alloys.
Owners of rigid machines equipped with low-speed spindles can use “helical” cutters.
Production speed and component quality can decline when a milling process struggles with chip evacuation.
One of the most popular techniques for increasing MRR is high-feed milling, which combines milling at fast feed rates with relatively shallow cutting depths.
Optimized roughing removes material even faster than high-feed milling to produce part geometries close to the desired shapes.

Experts share tactics that let machinists use new tools and techniques to drive up metal removal rate (MRR).

Shops interested in maximizing ***metal removal rate*** (MRR) in milling operations can choose from among a number of tools and techniques that won’t break the bank and don’t require unacceptable sacrifices in tool life or machining quality.

One recently introduced material innovation is aimed at increasing speeds and feed rates during milling of high-temperature alloys, a group of high-strength materials that includes titanium, Inconel and PH stainless steel. This new milling grade, ***KCSM40***, improves the thermal resistance of cutting-tool inserts used to machine high-temperature alloys, according to Kennametal, of Latrobe, Pennsylvania, which developed the carbide insert material.

Introduction of Ti-6Al-4V Milling Machine

Users of inserts made of KCSM40 are now machining Ti-6Al-4V at 160 surface feet per minute when they might have reached only 140 SFM in the past, while also getting longer tool life, says Scott Etling, Kennametal’s director of global product management for indexable milling.

Etling points out that cutter bodies have different "densities" based on the number of inserts in the cutter. A 4-inch diameter cutter, for example, could have 8, 12 or 15 teeth, with a 15-tooth cutter of that size considered very high density.

"If you're capable of running a 15-tooth cutter, you're improving your productivity because you'll have more teeth in the cut," he says.

The more teeth in the cutter, however, the more spindle horsepower it will require, so some milling machines may not pack the power needed for a higher-density cutter. And even if they do, the milling fixturing might not be rigid enough to handle the increased force these cutters produce.

"We tell everybody to make sure they understand their spindle, do their cutting-force calculations and then go with the highest-density cutter they can," Etling says.

Owners of rigid machines equipped with a low-speed spindle can use a "helical" cutter such as Kennametal's new Harvi Ultra 8X, which is designed to offer longer tool life than traditional cutters at high MMR. ***Helical cutters*** feature multiple rows of inserts.

For example, a 3-inch diameter helical cutter could have five rows equipped with 11 inserts each. "With 55 inserts with radial engagement, you are machining at a traditional feed rate but removing a lot more material," Etling says.

It's also important to use the right ***coolant*** flow, pressure and viscosity to maximize MRR in milling operations. "Machine tool builders have designed terrific machines, and users should be running their cutting tools at the highest speeds and feed rates their machine allows," Etling says.

Improve Chip Formation and MRR with Coolants

Both production speed and component quality can decline when a milling process struggles with chip evacuation. Designed to mill grooves up to 6 millimeters wide, the ***CoroMill QD*** cutter from Sandvik Coromant, of Fair Lawn, New Jersey, uses geometry and a novel coolant delivery system to solve chip-related problems.

The QD's insert geometry produces chips that are thinner than the groove being machined. These chips are flushed out by coolant delivered through the cutter body to each cutting edge. Besides boosting MRR, this system dramatically increases tool life and the surface quality of milled components, says Joseph DeRoss, product milling specialist at Sandvik Coromant.

Sandvik Coromant points to user data showing that the QD can remove metal about 20 times faster than competitive cutters. In addition, the company reports that in one case the QD machined 75 parts before the inserts wore out, compared with just 10 parts for a competitor's tool.

Though thinner chips are desirable in this case, chips that are too thin indicate that cutting action and the resulting heat are restricted to a relatively small portion of the insert edge, which can lead to cratering, flank wear and thermal cracking. In fact, thin chips are a common cause of low milling productivity and reduced tool life.

On the other hand, chips that are too thick are an indication of very high cutting forces that could cause insert breakage. The key is to determine the feed rate that yields the maximum chip thickness but won't overstress the inserts.

"If you thicken the chips, you'll put them on the floor faster; plus, you get longer tool life," says DeRoss. Achieving the proper chip thickness can boost milling productivity by 20 percent or more, he adds.

Chips should always be thick when a milling cutter enters the workpiece material and thin at the exit.

When a cutter is programmed to enter straight into the material, however, thick chips will be produced at the exit until the cutter is fully engaged with the material. The unwelcome results of this include poor surface finish at entry and reduced tool life, as well as jarring noise and excessive vibration.

According to DeRoss, there are two ways to avoid the consequences of straight-entry cutting. One is to reduce the feed rate by 50 percent until the cutter is fully engaged. The other is to program a "roll" into the cutter motion. This technique arcs the cutter clockwise, which eases the inserts into the cut, DeRoss explains. The resulting chip thickness on exit is always zero, he says, eliminating straight-entry problems without slashing the feed rate.

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Move to High-Feed Techniques

One of the most popular techniques for increasing MRR is high-feed milling, which combines milling at fast feed rates with relatively shallow cutting depths. A small lead angle on the bottom of inserts used for high-feed milling reduces the average chip thickness, which in turn boosts feed rates, says Tim Aydt, indexable milling product manager for cutting-tool supplier Seco Tools, of Troy, Michigan.

"Now, you're looking at possibly feeding at 200 to 300 inches a minute as opposed to 30 to 60 inches a minute," Aydt says.

On the downside, feeding at these elevated rates makes high-feed milling a roughing technique, so users might have to follow with a secondary operation to get the required part finish.

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> Indexable Milling Product Manager, Seco Tools

Consider Adopting Optimized Roughing

Another popular roughing operation, often referred to as optimized roughing, removes material even faster than high-feed milling to produce part geometries close to the desired shapes. Then, a follow-up operation can produce the final geometry and surface finish.

Optimized roughing combines deep cut depths with light radial engagement. The low radial cutting forces reduce stress and wear on machine spindles. In addition, tool life increases because less heat is produced during cutting. Under the right conditions, in fact, cutting tools used for optimized roughing can last up to eight hours when machining titanium, compared with 30 minutes when conventional cutting methods are used, Aydt says.

Reduced heat and radial depth of cut are also responsible for the dramatic increase in machining speeds. Pockets, for example, can be machined up to four times faster than they can with conventional methods. Optimized roughing is also well-suited for machining straight walls that require long axial cut depths.

The technique can be used on any material, says Jay Ball, Seco's manager of solid milling products. "We've found that optimized roughing of high-nickel alloys is very beneficial," he reports. "We also see customers using the strategy on stainless steel, cast iron, model tool steels and even aluminum."

Ball says the move to optimized roughing is probably the main trend he sees among those trying to increase their metal removal rates. "It's the biggest thing since sliced bread right now."

Key Takeaways

A variety of new metal removing machines, technologies and techniques are speeding up milling rates.

You need to make sure you are using the right coolant flow, pressure and viscosity to maximize MRR in your milling operations.

High-feed milling likely means you will be roughing, which will require follow-up operation to finish.

What are your best techniques for improving metal removal in milling? Share your experience.

