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cover story

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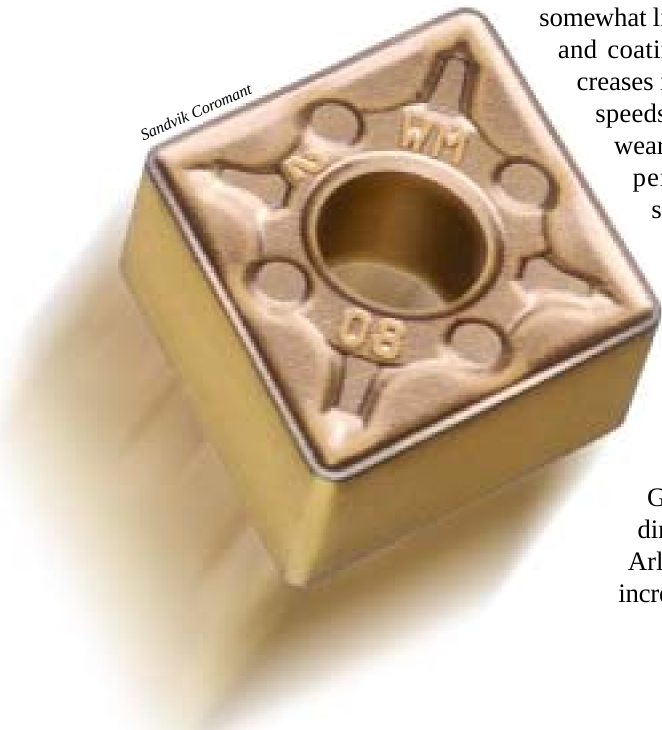
Take a Bigger Bite

Manufacturers raise turning productivity by boosting feed rates.

The drive to increase turning productivity hasn't slowed since the invention of the lathe. Over the years, however, the ways to boost output have changed.

Great leaps in productivity followed tool-technology breakthroughs, like the development of carbide tools and wear-resistant coatings. Other giant steps in tool technology may occur in the future. But recent advances have been less dramatic, such as optimizing machining parameters and tool geometries.



The meaning of "optimizing" has changed, too. Traditionally, shops cut production time by increasing DOC and reducing the number of passes needed to machine a part. Today's near-net-shape manufacturing techniques, as well as the toughness and wear-resistance of modern inserts, have minimized the need for multiple cuts. For many parts, shops are taking just one pass or, at most, a medium cut and then a finish pass.

The potential for increasing speed is somewhat limited, too. New substrates and coatings allow incremental increases in cutting speeds, but those speeds can result in higher tool wear. In some cases, only a 20 percent increase in cutting speed will decrease tool life 50 percent.

Feeding Faster

For many operations, making more parts faster starts by increasing the feed rate.

According to Mike Gadzinski, national training director for Iscar Metals Inc., Arlington, Texas, a 20 percent increase in the feed can result in a manufacturing cost reduction of 15 percent or more.

The following illustrates the savings possible by raising the feed from 0.010 ipr to 0.012 ipr when turning 5,000 parts. The burden rate is $60/hr.

Feed rate: 0.010 ipr
Part length: 12"
Lot size: 5,000
Cutting speed: 500 rpm
500 x 0.010 ipr = 5 ipm cutting time
12" length ÷ 5 ipm = 2.4 min./part
5,000 parts x 2.4 min./part = 12,000 min. (200 hrs.)
200 x $60/hr. = $12,000

Feed rate: 0.012 ipr
Part length: 12"
Lot size: 5,000
Cutting speed: 500 rpm
500 × 0.012 ipr = 6 ipm cutting time
12" length ÷ 6 ipm = 2 min./part
5,000 parts × 2 min./part = 10,000 min. (166.67 hrs.)
166.67 × $60/hr. = $10,000

SAVINGS: $2,000 (16.67 percent)

Although raising the feed rate lets a manufacturer turn out parts more quickly, there are other considerations.

Among them is surface finish. Simply jacking up the feed can lead to the production of a part that looks like a barber pole. That's because surface finish is a direct reflection of the relationship between feed rate and the radius of the insert corner, or nose. Mathematically, the relationship is:

$$R_a = \left(\frac{\text{Feed}^2}{8 \times \text{Nose Radius}} \right) \times 317{,}500$$

The larger the nose radius, the lower the R_a number and, thereby, the finer the finish (Figure 1). The rule of thumb for achieving an average finish is that the feed should not exceed half the nose radius.

Often, simply using an insert with a larger nose radius will allow higher feeds. Many parts require just a straight turn and a face, with no shoulder or anything special involved, Gadzinski said. These types of parts can be readily cut with larger-nose inserts.

Many shops don't, though. They continue, out of habit, to buy inserts with the same nose radius. The most common are CNMG-432 and WMNG-432. Gadzinski said that changing to a -433 or -543 (3/64" nose radius) insert, for example, would permit higher feed rates while providing a good surface finish.

Prasad Boppana, turning-products manager for Valenite, Madison Heights, Mich., cautioned against applying large-nose-radii inserts at higher feeds when machining long, slender parts and thin-walled components. "If you select a large nose radius, you're going to create radial pressure, because you're cutting with a circle rather than a point. The increased forces can create bouncing and chatter."

Todd Callaby, director of engineering for Toshiba Tungaloy America Inc., Itasca, Ill., said that it's not always possible to increase the feed. The lathe or turning center may lack the necessary rigidity, or the integrity of the machine's bearings may not be up to the task. The rigidity of the workholding system also must be considered when boosting feed rates.

Moreover, as the feed increases so does tool pressure. Too much pressure can accelerate diffusion or crater wear, or even cause nose deformation. New coatings and substrates minimize these problems.

"Crater wear is not the problem it used to be," said Gadzinski, thanks to the "new substrates and high-performance coatings that all tool manufacturers are using today."

The thicker chips generated by heavier feed rates also absorb heat that might otherwise enter the cutting tool and promote crater wear. Boosting feeds can reduce other tool-wear contributors as well.

Doug Ewald, manager of lathe-product marketing for Kennametal Inc., Latrobe, Pa., said increasing the feed rate reduces the number of linear inches that pass the cutting edge. That minimizes flank wear.

Take the Lead

Another feed-boosting strategy involves changing the lead angle of the toolholder.

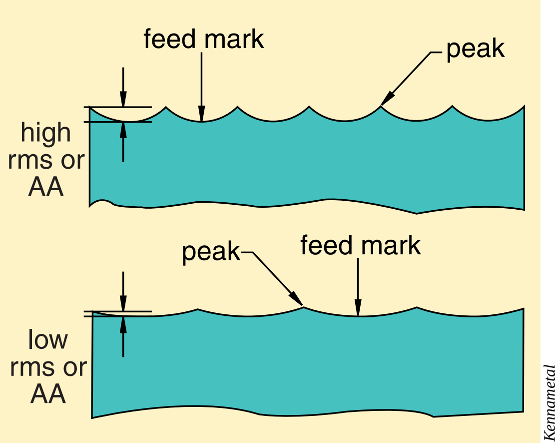
Bill Tisdall, turning-product specialist for Sandvik Coromant Co., Fair Lawn, N.J., recommends placing a square insert in a 45° holder instead of taking a C-style (80° diamond) insert and putting it in a toolholder with a -5° lead angle (Figure 2). "You will actually thin out the chip about 30 percent. Chip thickness is basically your feed rate, so that's at least 30 percent more feed you can put into the application."

The change has no effect on surface finish, and the square insert also has more usable edges than a diamond-shaped one. Tool life may improve, too, because the cut is spread along more of the cutting edge. Doing this is especially beneficial when turning high-strength materials, such as superalloys, because it reduces DOC notching of the insert edge.

According to Tisdall, shops that serve the gas-turbine industry typically mount a square insert in a 45° holder to remove scale, an application wherein the main tool-failure mechanism is DOC notching.

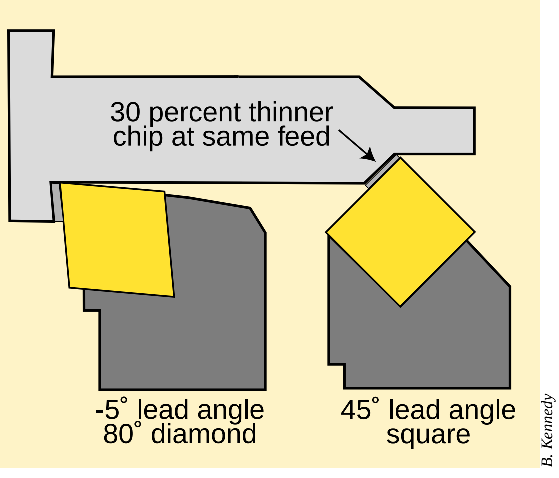
The approach has disadvantages, though. Tisdall said: "Because you've got that bigger lead angle, you're directing more force into the part. Instead of directing it into the chuck, you've got more radial force. It's a chatter problem. If you don't have a big, bulky part, you can get into trouble. Also, you can't turn to a shoulder if you run a 45° lead."

The best time to apply a 45°-lead holder is on a part with no shoulder or when machining a part with a shoulder that involves multiple tool changes. Before the finishing pass on the latter part,



Kennametal

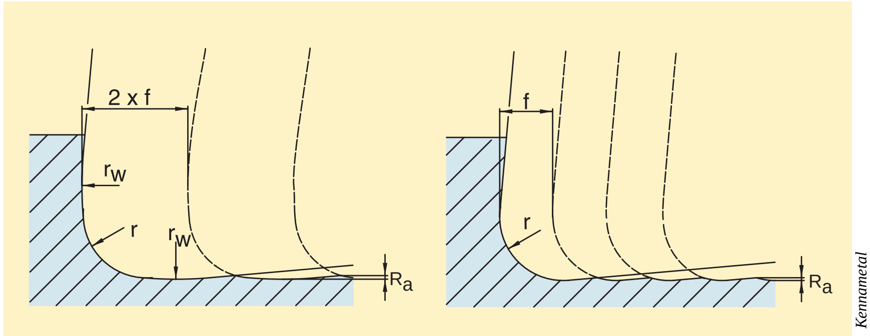
Figure 1: An insert with a small nose radius (top) leaves a rougher finish than one with a larger nose radius (bottom).



B. Kennedy

Figure 2: Changing from an 80° diamond insert in a holder with a -5° lead angle to a square insert in a 45° holder will allow the feed to be boosted approximately 30 percent.

apply a plunge-type insert to clean out the shoulder.



Left: An insert with a wiper radius (r_W) produces the same surface finish (R_a) at twice the feed rate (f) as a conventional insert (right) having an identical corner radius (r). When run at the same feed, the wiper can impart a 100 percent finer surface finish.

Wipers Arrive

In the last decade, wiper inserts have facilitated higher-feed turning. The action of these inserts mimic the longtime milling practice of following a primary cutting edge with a secondary, extended edge that smoothes, or wipes, the crests left by the primary edge. In the case of wiper inserts for turning, the extended edge consists of an extra radius that bulges slightly behind the nose.

Compared to conventional inserts, wipers benefit users two ways: When operated at the same speed, they can improve surface finish by up to 100 percent. And, they can be run at twice the feed while producing a finish equal to that what's achievable with a conventional tool.

Valenite's Boppana said, "If your end point for indexing is a 30µm finish, and you're operating [a conventional insert] at a 0.012-ipr feed rate, you could crank a wiper up to 0.020 to 0.024 ipr and still get the same finish."

A number of factors influence the effectiveness of wiper inserts, including the shape of the part. Iscar's Gadzinski said wipers work best in straight-part operations. "If you've got a lot of angles or contours, they don't work as well. They will still cut, but you'll get the same type of finish that you would with a conventional insert."

Sandvik Coromant's Tisdall said: "We think that in cuts with up to 5° of ramp, the wiper will be effective. But that varies. I've had guys say they lose the wiper effect in as little as 3°."

However, just because a part has acute contours shouldn't preclude the use of a wiper insert. As an example, imagine turning a 6" straight section on a workpiece, followed by a 1" ramp to a larger diameter, then another 6" straight section on the larger diameter. It would make sense to use a wiper on such a part, Tisdall said. "If you double your feed on the first section, when you ramp to the larger diameter, you just drop your feed back to the normal rate. Once you hit that larger section and start going straight again, you can double your feed rate again."

Ewald emphasized the importance of carefully matching a wiper insert to its toolholder. "You can't use them across the same range of lead-angle holders that you can with conventional inserts. You do find that there are certain holders in which wipers will work more effectively."

The added radius behind the nose of a CNMG or WNMG wiper insert makes no difference in terms of the workpiece dimensions it can cut. However, on more acute-angled inserts, like DNMGs and TNMGs, the wiper geometry does significantly change the shape of the nose.

Tisdall said, "You actually have part of the wiper radius sticking out past what we would consider to be the ANSI nose radius. It's kind of like a bulge." He added that manufacturers' literature contains offset tables for adjusting programmed toolpaths in the X and Z axes.

Because of the wiping action, contact between the wiper insert and workpiece is greater than with a conventional insert. This increases the chance of chatter occurring when machining at very light DOCs.

Gadzinski recommends leaving extra stock for finishing passes when possible. Many shops, he said, leave only 0.005" or 0.010" of stock when running -432 inserts. He advises customers to leave at least 0.015" to 0.020". "It's no big deal. You still are making the same number of passes, and the wiper insert cuts a little cleaner if there is a little more stock."

When a near-net-shape workpiece necessitates a light cut, Gadzinski suggests applying a smaller corner radius, or a smaller insert. "Use an insert with a 1 (1/64") corner radius instead of a 2 (2/64"), or even a smaller 3/8"-IC insert," he said. "There's no sense in buying a big -432 insert if you're only taking 0.030" of stock off. A smaller-nose radius will allow you to take a lighter DOC on smaller-diameter parts."

Chip control can be an issue when making finishing cuts. Exploiting the high-feed capabilities of wiper inserts should enhance chip control, said Tisdall, "because you're feeding harder, you're making the chip thicker and more prone to break." And because wiper inserts are meant to be fed at higher rates than conventional tools, their top-form geometries are designed for strength.

"Insert lands on wiper inserts—at say, 0.004"—are larger than those on true

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finishing inserts, which might be upsharp," said Tisdall, adding that manufacturers typically provide different wiper geometries for roughing and finishing operations.

Not Always Applicable

Toshiba's Callaby said that wiper inserts are an excellent technology, but they're not for every application—or for everyone. Their use on superalloys is limited, for example.

The reason why is that users of these alloys, such as turbine manufacturers, may seek increased feed rates, but "it's not so crucial for them," said Callaby. "They're not pumping out a million steering knuckles every month, like automakers, who are looking to cut seconds from their cycle times." Turbine manufacturers are concerned about the cost of the finished workpiece, and the cost of machining performed before finishing. They leave the quest for maximum feeds to others.

If you're one of those "others," higher feeds—achieved with conventional or wiper inserts—can help improve the productivity of your turning operations. The key to success is knowing the mechanics behind the strategies, and the limitations and benefits both types of inserts offer.