FEBRUARY 2002 / VOLUME 54 / NUMBER 2

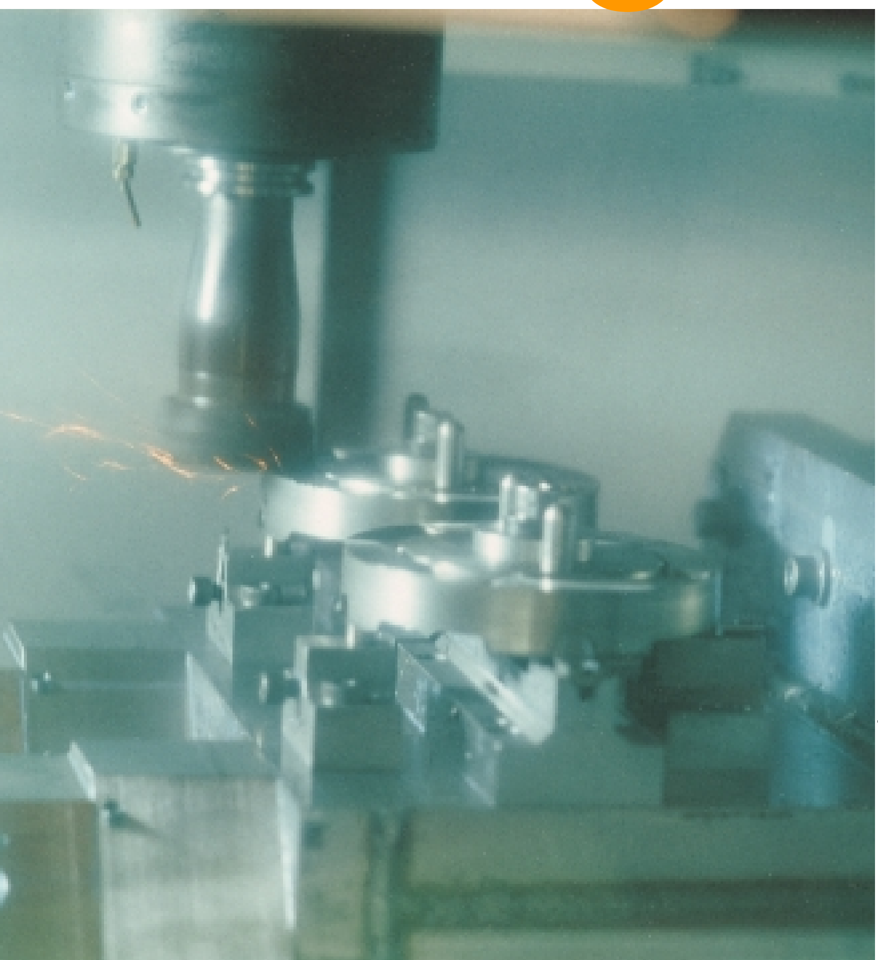
SPECIAL FOCUS: MAKING AUTOMOTIVE PARTS

Without a doubt, the automotive industry is critical to the U.S. economy's well being. The U.S. auto industry employs about 3.5 million workers, or 2.6 percent of the nation's workforce. The goods and services purchased by those people create another 3.1 million jobs, according to a University of Michigan study commissioned by the industry.

Although U.S. car sales were down last year compared to 2000's record-breaking performance, more than 17 million new vehicles were sold, according to preliminary figures from the Automotive News Data Center. This represents roughly $350 billion in sales, or 4 percent of the gross domestic product.

To showcase the importance of vehicle manufacturing for the metalcutting industry, we present four articles about making automotive parts in this issue. The first, which starts below, looks at some toolmakers' recent product offerings for facemilling auto parts. The second covers the advantages of plunge turning hardened parts, the third explains how to overcome the unique obstacles of machining automotive workpieces comprised of two metals, and the fourth reveals the findings of a study conducted by a consortium of automakers and their suppliers about dry drilling aluminum.

Facing Facts



Kennametal Inc.

► BY BILL KENNEDY, CONTRIBUTING EDITOR

Before the advent of animal rights, it was politically OK to say "there's more than one way to skin a cat" when describing another way to accomplish something. Today, in the automotive industry, there's more than one way to facemill an engine block.

Facemilling automotive parts is a classic example of approaching a single goal by many different paths. The objective of facemilling is clear: to produce a plane that brings a part to size or creates a mating surface. Toolmakers are introducing milling-cutter insert systems for cast iron, as well as other materials, that offer high productivity and impart surface finishes that enable automotive components to "mate for life."

Tool Life on the Line

The traditional transfer line evolved from automotive pioneer Henry Ford's original production-line concept. At each station, a machining operation occurs within a fixed cycle time and

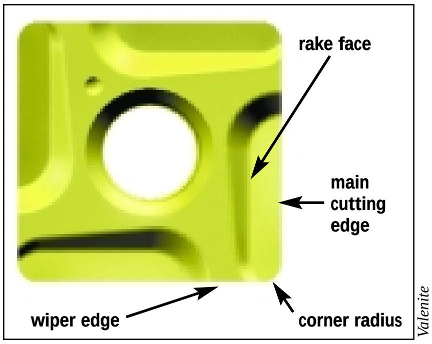


Figure 1: Valenite's new QC milling inserts can handle the iron family's dysfunctional structures through careful design of four distinct areas of the insert edge: the corner radius, the lead cutting edge, the rake face and a trailing flat wiper area.

then the part is transferred to the next station. The line moves only as fast as its slowest operation and, generally, speeds, feeds and tool paths are locked in. Changing tools at one station means stopping the whole line, so tool life—in specific increments—is crucial.

"It's a 'by-shift' thing," said Lee Reiterman, manager of product development for Valenite Inc., Madison Heights, Mich. "Half a shift or one-and-a-half shifts is no good. A tool that lasts one shift, with some insurance, is the first step. Then the goal is to increase tool life to two, three or more shifts."

Harder and tougher cutting tool materials and coatings are usually the first areas targeted when seeking to extend tool life. However, Reiterman thinks that tool geometries offer additional opportunities to make cutters last longer, especially when milling cast irons. He pointed out that the automotive industry machines a family of cast iron alloys, including gray, nodular and compacted-graphite, and all have different machining characteristics. While gray irons are abrasive and brittle, which makes them subject to breakout, nodular and compacted-graphite irons are sufficiently ductile to produce a chip, but they are also prone to burring.

Moreover, Reiterman said, variations in the casting process can produce different machining characteristics within the same workpiece. Rapid cooling of a thin section, for example, can produce extremely hard, difficult-to-machine structures. Machinability also can vary from batch to batch and from caster to caster.

Reiterman said Valenite's new QC milling inserts can handle the iron family's dysfunctional structures through careful design of four distinct areas of the insert edge: the corner radius, the lead cutting edge, the rake face and a trailing flat wiper area (Figure 1). When finishing or making shallow depths of cut, the corner radius is especially crucial. Under these conditions, the radius must be larger than the DOC. This creates a lead angle between the corner and the workpiece that is important for reducing breakout in gray irons.

Sharp edges are susceptible to breakage from casting variations, so the corner radius and lead edge are honed to preserve edge integrity. On the other hand, the wiper flat removes only the high points of feed marks left by the lead cutting edge. A hone reduces the wiper's cutting ability, causing it to simply burnish the surface. "So the wiper is left up-sharp," Reiterman said.

He added that the rake face is positive, to reduce forces, and is designed to efficiently evacuate chips. Matching edge geometry to workpiece material characteristics reduces cutting forces, minimizes heat buildup and extends tool life. Reiterman said the QC system has increased tool life 30 to 200 percent in a variety of cast iron milling operations.

Competition Drives Flexibility

The automotive industry is seeing a shift from the venerable transfer line to more flexible machining systems. Mike Gadzinski, national training director for Iscar Metals Inc., Arlington, Texas, believes outsourcing has helped fuel the trend. He said: "You might have two or three suppliers making the same part for a manufacturer. A supplier will buy machinery designed to make that type of part, but the sizes, materials and actual operations will vary. Maybe they'll run the same part five or six times a year, but the rest of the time they'll be running something different on that machine."

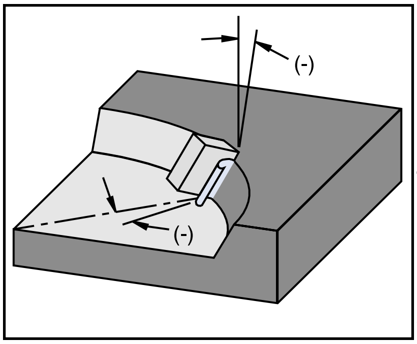
Because they are not bound to making just one part for one manufacturer, Gadzinski said suppliers are looking for cutting tools that are easy to set up during part changeovers and can be applied to a wide range of metals. In response, he said Iscar has developed a family of automotive milling tools called the Auto2000 milling system. The cutters feature a precision-ground seating ring that determines the axial height of each insert and saves time otherwise needed for presetting and adjustment. The tools can finish and semifinish gray, malleable and ductile irons common in the automotive industry, while taking a 0.200" maximum DOC.

Each octagonal OHNT insert (Figure 2) has 16 cutting edges, an axially positive chip former and a wiper flat. The positive chip former reduces cutting forces and the wiper flat improves surface finish.

Not Simply Faster

With CNC technology, in modular transfer lines or machining cells, it is easy to adjust cutting parameters to take full advantage of advances in cutting tool technology. For maximum productivity in milling gray iron, Tim Marshall, milling products manager for Kennametal Inc., Latrobe, Pa., said silicon-nitride ceramic tools are the best choice. He said cutting speeds of 2,500 to 4,500 sfm are typical, and that feeds and tool life comparable to carbide tools are possible.

Figure 2: Each of Iscar's octagonal OHNT inserts has 16 cutting edges, an axially positive chip former and a wiper flat.



Figs. 3, 4, 5: Kennametal

Figure 3: Negative geometries present a strong cutting edge, backed up by the bulk of the insert, but they generate large cutting forces and require enough power to "bull" through the workpiece.

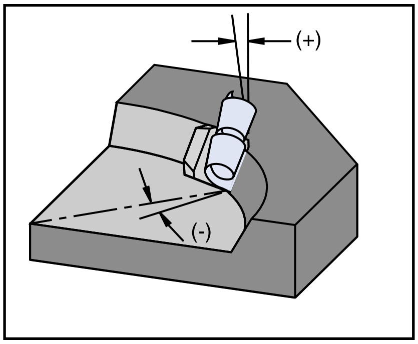


Figure 4: Shear-angle (negative radial and positive axial rakes) cutters have proven to be able to machine irons productively.

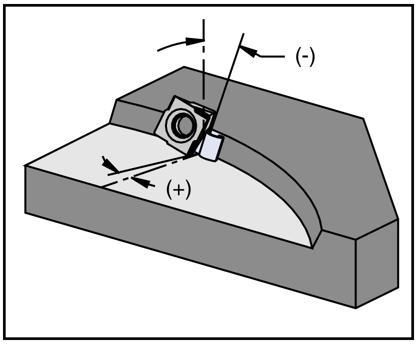


Figure 5: Kennametal's Fix-Perfect system features on-edge inserts with a reverse shear action: positive radial and negative axial rakes.

When it won a large contract to machine cast iron automotive components, Nationwide Precision Products Corp., Rochester, N.Y., tried Kennametal's Fix-Perfect inserts made from the toolmaker's Kyon 3500 silicon-nitride ceramic grade.

Dave Merritt, NPP's manufacturing engineering manager, said: "I knew what carbide tools were doing. I gave the ceramics a shot and the results were very impressive. Compared to carbide, we're running three or four times the feed rates."

Tool life also improved. In one application, a 1" solid-carbide endmill produced about 300 parts before regrinding was necessary. A 3" facemill with Kyon 3500 inserts produced well over 2,000 parts per edge, or 16,000 parts per eight-sided Fix-Perfect on-edge-style insert.

Merritt said, "We also knocked 40 to 50 percent off the machining time. We got much better tool life, decreases in cycle time and more throughput."

Merritt said ductile iron is more difficult to machine than gray iron, requiring an adjustment in cutting speeds. "For ductile iron, we machine at close to the same chip-per-tooth rate as gray iron, but we have to drop the surface speed a little bit. We might run 2,400 sfm on the ductile—in some cases up to 3,000 sfm—while we have run close to 4,000 sfm on the gray iron."

It's clear that advanced cutting tool materials, although more expensive than carbide, can provide increases in productivity that outweigh the increased tool costs. However, the machine tool in use must have sufficient horsepower and rigidity to handle the increased performance. "The ceramic offers high speeds, good tool life and a good metal-removal rate," said Marshall. "But if you've got a 0.150" DOC, and only a 20-hp machine, you won't be able to use it. You could run it slower, but you won't be taking advantage of the cutting tool's capability."

NPP's Merritt said, "We ran the parts temporarily on a lower-horsepower machine, and the silicon-nitride inserts didn't work as well. We didn't get the tool life because we couldn't make a big enough chip and we couldn't get the metal-removal rate that we wanted."

Geometric Progress

NPP's experience with ceramics doesn't mean lower-horsepower machines are doomed to mediocre productivity. The correct cutter geometry can expand the capabilities of the less-powerful.

Traditionally, cutters with negative axial and radial rakes have been the way to machine cast iron. Negative geometries (Figure 3) present a strong cutting edge, backed up by the bulk of the insert. But they generate large cutting forces and require enough power to "bull" through the workpiece.

In contrast, shear-angle (negative radial and positive axial rakes) cutters (Figure 4) have proven capable of machining irons productively. A shear-angle cutter cuts more freely and stabilizes the cut, enabling lower-horsepower machines to run tools made from advanced materials.

Positive-rake inserts are not as strong as double-negative tools for heavy roughing, Marshall said, but added that "with the edge preps available today, a shear-angle cutter can be very productive."

Depending on insert grade and application, edge preps can range from none (sharp) to 0.0005" to 0.003" hones to chamfers (T-lands). For maximum strength, an insert edge may feature a chamfer with the corners honed to blend into the insert surface. Marshall said that Kennametal's standard edge preparation for its Kyon 3500 ceramic insert grade is a 20° chamfer that's 0.008" wide. "It's there to protect the ceramic from chipping at high speeds."

Kennametal's Fix-Perfect system is a variation on the shear-angle theme. It features on-edge inserts with a reverse shear action: positive radial and negative axial rakes (Figure 5). Kennametal says the greater mass behind the cutting edge gives the on-edge insert increased strength, and the negative axial rake directs the cutting forces toward the spindle, stabilizing the cutter. The company says the negative axial geometry places the initial point of impact above the insert point and, in that way, protects it as the tool enters the cut.

Marshall said Fix-Perfect cutters with wiper inserts can rough and finish to a 32-rms surface finish in the same operation, eliminating a separate finishing pass and reducing cycle time.

He added that the company is introducing a new line of Fix-Perfect milling cutters designed specifically for finishing.

Material Shift

Because cast iron is rigid, has a high compressive strength and can be cast into complex shapes, it's long been the preferred workpiece material for engine blocks and other automotive components. However, a trend towards lighter vehicles, prompted by CAFE (corporate-average-fuel-efficiency) requirements, is reducing the amount of heavy alloys in vehicles. In 1980, according to the American Foundry Society, a domestic auto contained about 600 lbs. of cast iron. By 1999, that average amount had dropped by nearly half, to 325 lbs., and it's expected to fall to about 230 lbs. by 2006.

On the other hand, aluminum-industry analysts say automotive use of aluminum will grow 50 percent in 5 years, from around 250 lbs. per vehicle in 2000 to about 380 lbs. per vehicle in 2005.

"I don't know of one new iron block program that any Big Three automaker has in its immediate future," said Scott Markley, automotive product manager for Rockford, Ill.-based Ingersoll Cutting Tool Co. "People have been talking about aluminum for quite a while, but it's really happening now."

Maximum tool life on long production runs of aluminum parts, Markley said, requires superhard polycrystalline diamond cutting edges. Suppliers offer a variety of PCD grades for turning and milling applications. While PCD is one of the hardest materials known, its toughness is low. As a result, the primary cutting-edge failure mode for PCD tools is chipping.

An important factor in maintaining the edge integrity of relatively brittle PCD tools is equalizing cutting forces across the cutter's teeth. Precise adjustment, especially in the axial direction, is fundamental to extending tool life.

Markley said Ingersoll's cutters feature the Flex-Lok cartridge that provides precise adjustment and also maintain a setting over long periods of shelf life and run time. After securing the tangential insert with one movement, a barrel screw permits the insert position to be adjusted in fine increments. The precise adjustment allows the cutting load to be equalized among all the inserts in the cutter, maximizing tool life.

Aluminum alloys for automotive parts have unique requirements, with respect to tool geometries. Markley said that while gummy, low-silicon, aerospace aluminum alloys tend to be cut with more positive geometries, cast aluminum alloys for automotive generally have a higher silicon content. Because of this, they don't need such acutely positive designs, which tend to sacrifice cutting-edge stability. As a result, many milling cutters for automotive aluminums feature neutral axial and radial geometries.

Ingersoll's cutters for automotive aluminums have a slightly positive angle in both the radial and axial sense, to create the proper shearing action. These tools don't "plow" through the part, like in cast iron and other ferrous materials, but rather lift the material and create a manageable chip, Markley said. He reported that for one milling application on an aluminum intake manifold, the slightly positive geometry produced twice the tool life of a neutral-geometry tool.

Flexibility and Performance

Jim Flueckiger, executive vice president and general manager for Mil-Tec USA Inc., Lehigh Acres, Fla., said current economic conditions are driving automotive manufacturers to seek greater productivity while minimizing capital and tooling expenses.

Mil-Tec's Freedom Cutter, he said, reduces tooling inventory and provides aggressive insert geometries. Cutters include shell mills from 2" to 6" in diameter, large facemills from 8" to 12" in diameter, 1.5"-dia. drills and milling tools, and 1"- to 8"-dia. finishing cutters. The pockets of all the cutters are designed to hold the same 0.625"-IC inserts.

The inserts feature flat-top, medium-dish or high-positive geometries with hones and chamfers engineered for different materials and machining parameters. Flueckiger said, "Our inserts feature very high, super-positive geometries with reinforced edges. We actually scoop the material instead of semi-pushing it. The geometries enable us to carry higher chip loads."

Mil-Tec field representative David Lingenfelter said one shop, milling "nasty" (28 to 30 HRC) ductile iron dies for an automotive customer, was able to go from a 30-ipm feed and 0.150" DOC to a 80- to 100-ipm feed and 0.250" DOC by applying the company's heavy-duty tooling.

Productivity the Hard Way

Many automotive components require hardening to meet final performance specifications. Often, the parts are machined before heat-treatment and are later ground to their final dimensions, in part to compensate for the distortions produced in the hardening process.

However, grinding operations are slow and produce an economically and environmentally burdensome coolant/chip mix called "swarf." To help manufacturers save time and money, toolmakers are developing tools that permit machining of hardened parts. Out of ne-

The following companies contributed to this article:

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Kennametal Inc.
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Mil-Tec USA Inc.
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Nationwide Precision Products Corp.
(712) 272-7100
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Sandvik Coromant Co.
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cessity, the tools must have extremely hard cutting edges.

"If you're machining ferrous materials, you use CBN or ceramics," said Kevin Mayer, director of advanced materials for Sandvik Coromant Co., Fair Lawn, N.J. "For nonferrous materials, it's PCD."

Sandvik is introducing a line of ceramic, CBN and PCD inserts for its familiar Coromill line of milling cutters. "If a manufacturer has been using these mills with carbide grades, they can just screw in these new inserts and machine harder materials or run at faster spindle speeds," said Mayer.

The new products include a selection of CBN tools and wiper inserts that impart finer surface finishes than are possible with roughing inserts alone. Mayer reported that Sandvik's grade CB50 CBN-tipped inserts achieve a finish of 16 R_a when milling automotive iron.

Sandvik's OEM Manager Jeff Rizzie added that advanced materials like CBN and ceramic enable CNC machines to perform some of the operations formerly limited to the high-horsepower transfer lines tooled with large cutters. "These CNC machines typically have higher spindle speeds, and the advanced materials enable them to run at those speeds and make use of all the horsepower they have available," he said.

Today's automotive milling products provide both productivity and quality, enabling manufacturers to kill two birds with one stone (uh-oh, here come the PC police).

And it appears that tool providers will continue to offer tooling systems that keep pace with the industry's rapid rate of change.