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BY BILL KENNEDY, CONTRIBUTING EDITOR

A Better Edge

Proper edge preparation improves tool performance.

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Depending on what you need to cut, you might choose a razor blade or an iron wedge. This basic concept holds true in metalcutting. For a soft material, a sharp-edged cutting tool usually does the job. But when machining harder materials, a sharp edge can be a liability. Up-sharp edges on carbide, ceramic, polycrystalline diamond or polycrystalline cubic boron nitride cutting tools tend to chip, resulting in shorter tool life and poor surface finishes.

In the early days of carbide tools, the solution was to round the edge with a hand hone to strengthen it. Those edge preparations were relatively crude. Today, cutting tool makers routinely apply hones from 0.003" (the diameter of a human hair) to 0.001" by a number of methods, including dry and wet blasting, slurry honing, tumbling and brush honing. Some are as small as 0.0003", while hones as large as 0.008" protect cutting edges when hogging.

Cut or Push

Controlling the size of the edge preparation is important. A hone can preserve the edge, but bigger is not necessarily better. Too large a hone—relative to the size of the uncut chip or feed rate—increases cutting forces and tool temperatures. Not until the hone is half the size of the feed, or less, does its impact on cutting forces and tool temperatures become minimal. Effective hones are usually one-third to one-half the size of the feed. For example, when an edge with a 0.002" hone feeds into the workpiece at 0.004 ipr, the hone is half the size of the uncut chip yet effectively protects the tool's edge.

Edge preparation has a significant effect on cutting forces, surface finish, residual stresses, burr formation and wear rate. The tool may be hogging a lot of metal, but the efficiency of the cut is determined in the tiny band that represents the relationship of hone size to feed.

Underappreciated Prep

Edge preparation has not received the amount of attention given to other tool features, such as the substrate and coatings. William J. Endres, Ph.D., associate professor in the Department of Mechanical Engineering—Engineering Mechanics at Michigan Technological University, Houghton, Mich., has studied edge preparation for more than a dozen years. The effects of edge preparation are underappreciated, he said, because "the control of edge prep has not been particularly good. It's hard to assess in any solid fashion the effect of a variable when you don't have good control of that variable in the first place."

He said many tool users are accustomed to thinking of hones in terms of A, B or C sizes, each of which has a wide tolerance range. In addition, hones often are applied inconsistently. Over the years, Endres has measured hones on a large number of tools and found "statistically significant variations from

A drill with engineered-microgeometry edge preparation enters a titanium workpiece.

edge to edge on an insert, from insert to insert in a box and across boxes. It's all over the map."

A Nonuniform Process

The nonuniform nature of the cutting process magnifies the detrimental effect of inconsistent edge preparation. Hones are usually applied uniformly along a tool's edge, but cutting conditions vary greatly along a single cutting edge. At the leading edge, the uncut chip thickness is heaviest and the edge requires maximum protection. At the tool's trailing edge, however, uncut chip thickness decreases to near zero while the hone remains the same size. Chip thickness at the trailing edge is smaller than the hone, so the cutting edge removes material inefficiently, which increases friction, cutting forces, temperature and wear rate.

Endres also found that the common brush honing process tends to overhone the tool corner radius, or trailing edge, producing larger hones on the corner than on the leading edge. "This is the opposite of what you want to do," he said. "You really want the edge radius to be smaller on the corner of the tool because the uncut chip thickness decreases along the corner radius."


B. Kennedy

Conicity Technologies' Bill Shaffer monitors a brush honing machine he developed to create uniform or variable edge preparations.

Controlled Variability

About 4 years ago, Endres met Bill Shaffer, executive vice president of Conicity Technologies LLC, Cresco, Pa. Shaffer had developed a brush honing machine that could precisely control hone size, shape and placement to produce an engineered microgeometry (EMG). The process employs dense silicon-carbide filament brushes similar to those used in standard brush honing machines. The difference is the machine's CNC precisely directs the tool while the edge preparation is being applied. Shaffer claims the machine can consistently control the size of the EMG on all edges of a tool to within 0.0003" of the specified hone.


B. Kennedy

Dense silicon-carbide filament brushes hone a cutting tool, which is precisely directed by a CNC.

"The functional design of the machine is versatile, but simplistic. The heart of it is the software," he said. Machine operation is based on lean manufacturing principles, enabling rapid changeovers of both the tools and the brushes.

The Conicity machine can create uniform edge preparations and EMGs, which vary in size along a cutting edge. "With the variable EMGs, the primary cutting edge is sized to match the infeed rate of the tool, or to be just large enough to fend off chipping in the workpiece material being machined," Shaffer said. "The edge prep on the portion of the cutting edge that transitions around the cutting nose or corner radius of the tool changes in size to maintain the correct ratio of edge prep size to the thickness of the uncut chip."

Honing In on Costs

Inconsistent and misapplied edge preparations can cause wide fluctuations in tools' wear lives. As a result, end users may be forced to set part counters to match the lowest predictable tool life, wasting potential tool utilization and increasing the tool cost per part. Tool failures cause downtime, which is even more costly.

Nowhere are costs more closely scrutinized than in the automotive industry. Commodity-management supplier EWIE Co. Inc., Ann Arbor, Mich., which manages more than 70 CMS contracts within the automotive and related industries, continually searches for new technology and processes to help its customers reduce tool costs. Tom Connelly, EWIE business unit manager, said: "We're not an advocate of price alone, we're an advocate of technology that's going to reduce total cost. The real emphasis is on quality and improving jobs per hour throughput. If you can do something that equates to more uptime, more throughput, that's where the real dollars are."

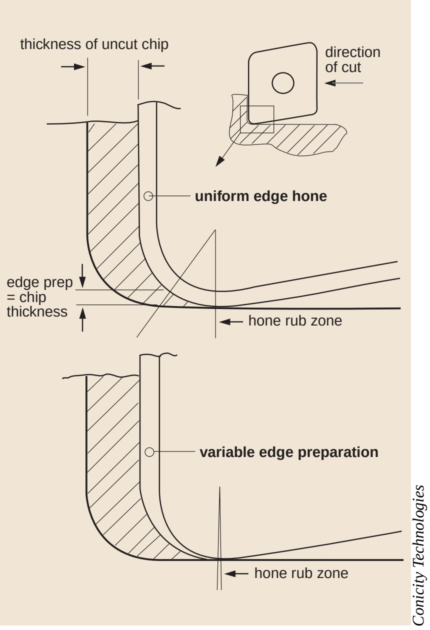
As part of EWIE's cost-reduction efforts for Ford Motor Co., Connelly arranged for tests of Conicity edge preparations in Ford facilities. At the Romeo (Mich.) Engine plant, manufacturing engineer Kevin Beaton tested variably edge-prepped milling inserts as a way to extend tool life when machining aluminum heads for a V-8 engine. The heads were originally being milled with a 10"-dia. cutter, tooled with 30 upsharp PCD inserts. The inserts were changed after milling 60,000 to 80,000 heads. Beaton said the change was necessary due to the formation of a fine burr on the water passages and combustion chambers that could possibly drop onto the head gasket during engine assembly.

Beaton tried a number of ways to eliminate the problem, including mounting a variable-frequency drive with servofeed on the transfer line. "We played with everything we could play with," he said, but never achieved the desired improvement.

For the test, Conicity designed and applied an EMG to the PCD inserts. With the new edge preparation being the only change, a cutter was able to mill 275,000 heads before insert wear necessitated a tool change.

Shaffer said a milling tool has a primary and secondary cutting edge. The primary edge takes the impact of the interrupted cut and requires an edge preparation to prevent chipping and accelerated wear.

"But," he said, "once the tool is engaged in the workpiece material, chip thickness changes dramatically at the tangency of the tool. At the very bottom of the tool, you're cutting just a trace of material if you're cutting anything at all. At that point the tool should be sharp again. If you have an edge preparation that runs uniformly around the nose of the tool, you start trapping material."



Because the bottom of a tool cuts just a trace of material, uniform edge preparation traps material at the tool's nose as it cuts, whereas a tool with variable edge preparation has a minimal hone-rub zone.

The situation is the root cause of burr formation, he said. "You start generating heat, increasing pressure and you soften the material. Typically, the material does not cut properly. It just lays over, and you just push it off the side of the part. Tools with Conicity's EMG rough, semifinish and finish simultaneously."

Along the Cutting Lip

Another EMG remedied the short tool life and breakage of drills used to make holes for bolt caps on P/M connecting rods at Ford. The drills lasted only half a shift and produced 1,500 holes before severe wear dictated changing them. Unpredictable breakage was also a problem. Six regrinds were possible before the drills were discarded.

The drills were replaced with tools that were identical except for the EMG, which varied along the drill's cutting lip. The replacement drills produced 3,200 holes. Both the drills used previously and the replacement drills were reground after every shift.

However, wear of the replacement drills was much less, and each replacement drill could be reground 10 times before disposal was necessary. Total tool life for each replacement drill reached 32,000 holes, compared to the 9,000-hole limit of the cutting tools used previously.

Precise control of the edge preparation clearly can improve tool life. But further benefits are available. Shaffer said, "What we do certainly pays dividends in tool cost reductions, but it represents something much greater. EMGs make the tool stable, offering an opportunity to increase feed rates."

Useful Understanding

Similar to tool-coating services, Conicity provides contract edge preparation services to end users and tool fabricators. And in addition to solving manufacturers' problems, Shaffer prepares tools to aid Endres' continuing efforts to fully understand the effects of tool geometry.

Endres said, "The goal of my work, and Bill has been very supportive of it, is to find the combination of edge prep—uniform or variable—and what I call the tooth profile, the corner radius and lead angle and everything else, that is the best of what is available."

Determining what is best involves balancing different quality measures, such as dimensional accuracy (forces), wear rates, surface finish, burr formation and residual stresses. He said: "Depending on the application, you worry about some things more than others. You can't just optimize on one. Edge prep is a huge factor in all of these things."

Endres said interest in the effects of edge preparation is growing. "People I've worked with in the industry, mainly the Big Three and Tier 1s, very much want to understand what's going on with edge prep," he said. "They know that it does something, they know it helps, but it can also hurt you. You want to put on the right amount. If you put on too much or put it in the wrong place, it's going to make the problem even worse."

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