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Identifying proper micro-endmill geometry

The smaller the endmill diameter, the higher the price of the tool. There is a reason for that—micro-endmills are a breed all their own. The smaller the diameter, the more precise the endmill needs to be. Tolerances are tighter, increasing the level of difficulty in manufacturing a micro-endmill.

Micro-endmills require specialized CNC grinding machines, some of which limit the largest achievable diameter to 0.080". These grinders require the tightest of tolerances, extreme accuracy, and temperature and vibration control. Their work envelopes are very small compared to the CNC grinding machines used to make endmills 1" in diameter and larger.

Endmills vary in quality, but why? You would think that since most toolmakers have access to the same CNC grinding machines, software and grinding wheels, that one endmill wouldn't differ much from the next. Moreover, tool users can specify the diameter size, end shape, number of flutes, length of cut and overall length they want. They can also specify tool geometry, helix angle, index and even different tool coatings. With that amount of control over the tool they get, what could go wrong?

Unfortunately, those factors only scratch the surface of the decisions made by toolmakers during the endmill manufacturing process. There are up to 21 different attributes and geometric features to choose from during that process. This is true for endmills from 0.001" in diameter to those larger than 1".

And, each attribute has its own set of variables, leaving the combinations that can be created on each endmill far too numerous to count. However, by industry standards, just about any variation can be considered acceptable or "within endmill tolerance." But just because some of these variations can pass inspection doesn't mean they should.

Attributes the toolmaker must select include land widths, flute depths, core diameter, axial clearance angles, rake angles, gash and web thickness, just to name a few. It's the combination of different attributes that make one endmill work great and another not-so-great. Toolmakers determine what is and isn't acceptable, including how tight or loose they will hold tolerances and how often they will make adjustments during the manufacturing process to precisely hold geometry.

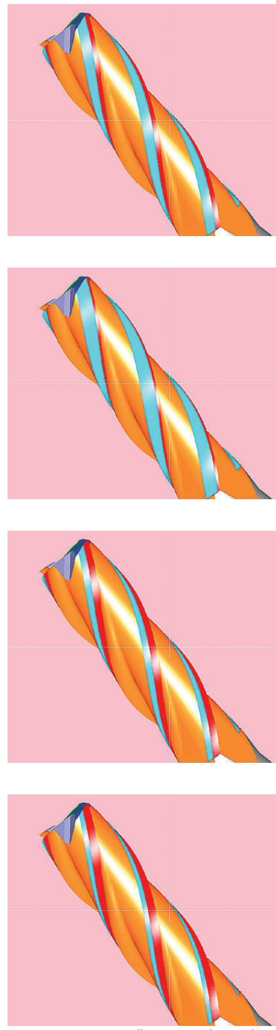
Figure 1 depicts variations in primary and secondary land widths on endmills. All the tools could technically be considered within tolerance, but each would perform differently. The red line is the primary land in each. Notice that the width (thickness) changes in each illustration. The images illustrate the differences between ideal (top) and less-than-optimal ratios (bottom three) for primary and secondary land widths. The endmill in the top image has a combination of features that make it stronger and offer more support to the cutting edge. The bottom three images show ratios that would meet industry tolerances, but not necessarily perform at optimal levels. For example, if the primary land width is too wide, the endmill can rub during use. If the land width is too thin, the cutting edge will be weak.

Figure 2 shows a web and gash on a 0.040"-dia., 2-flute ballnose endmill. It demonstrates what you should see when viewing the top of a high-quality micro ballnose endmill. Notice the white line running in almost an S-pattern across the top of the endmill. This is the cutting edge.

Cheaper endmills often feature a straight gash along the top of the endmill because it's easier to grind a straight gash on a ballnose endmill than the S-pattern shown in the photo. However, a straight gash is not optimal because it generates more pressure on the cutting edge. This is due to the entire cutting edge making contact with the workpiece all at once.

Figure 3 shows a web, or gash, that is too thin. There is not enough "meat" in the center of the endmill. (In manufacturing terms, this is called "breaking center.") This endmill will not perform as well as the endmill in Figure 2.

Each endmill manufacturer has its own recipe, or "secret sauce," based on what it feels are good or bad geometry combinations.



All images: Advanced Tool

Figure 1: The top image shows an ideal ratio for primary and secondary land widths, while the bottom three images show substandard ratios.

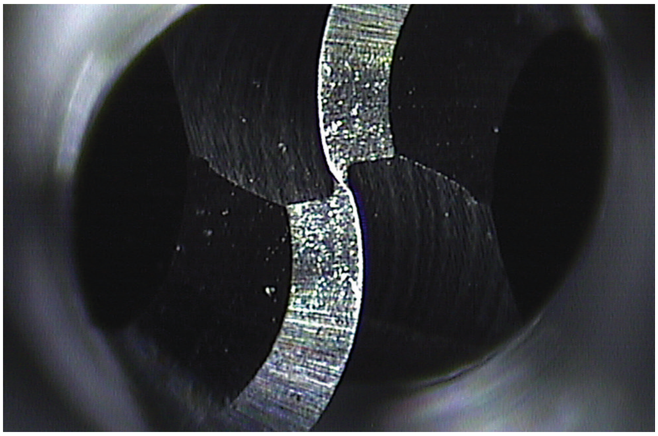


Figure 2: Ideal cutting edge on a ballnose endmill.

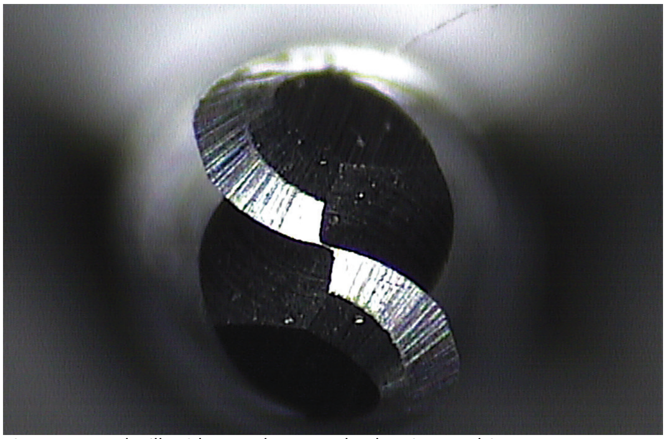


Figure 3: Endmill with a web, or gash, that is too thin.

These combinations are based on the company's experience working with different tool materials. One toolmaker's recipe may also be based on its position in the marketplace. If it uses a price-driven business model, some attributes may be eliminated to meet price points. For example, it is common in micro-endmill manufacturing to grind only a primary land rather than grind a primary and a secondary land.

One of the biggest problems that arises in the production of micro-endmills is that improper handling can lead to nicks or other flaws being imparted to the cutting edge by the operator. Carbide is fragile and breaks easily. When handling endmills with diameters that can't be seen by the naked eye, the operator making the tool might accidentally damage a cutting edge and never know it. The only way to identify damage on the smallest endmills is to view them under a microscope.

Figure 4 shows a 0.030"-dia., 2-flute endmill with a small nick on the bottom cutting edge. This kind of damage is often introduced by improper handling during grinding or tool coating.

Endmills are handled twice during the manufacturing process: when the tool blank is loaded into the grinder, and when the finished tool is unloaded. Coating, however, requires handling the endmill multiple times: for cleaning, coating and several post-treatments, if needed. This creates multiple opportunities to nick a cutting edge. That is why it is critical for toolmakers to have proper in-house processes in place or to partner with tool coaters that address these concerns. Operators must be properly trained in handling and inspection.

To get the most out of their milling applications, micro-endmill users must know how to select the proper tool and toolmaker. Each year, manufacturing engineers spend countless hours testing new and improved endmills in hopes of getting better results, reducing manufacturing costs and boosting the bottom line. They often search for faster speeds and feeds, longer tool life and improved surface finishes.

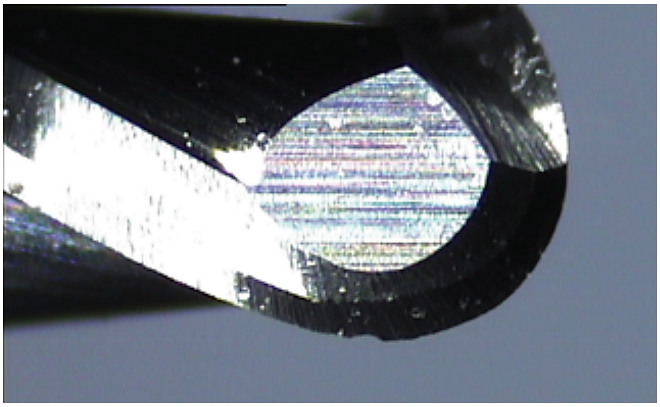


Figure 4: Endmill with a nick on the bottom cutting edge.

These goals are not easily accomplished, because all applications are not created equal. What works in one environment and setup may work differently even in a similar environment with a similar setup.

Navigating the sheer number of endmill manufacturers and endmill combinations in the market can be time-consuming and mind-boggling, but having a better understanding of good and bad geometry can ease the selection process. µ

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