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Many factors contribute to the success of an endmilling operation. Among them is applying a tool with the appropriate number of flutes.

Flute Count

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Every endmill has subtle features that impact its ability to effectively cut a family of metals. To the untrained eye, the differences may not be noticeable.

For example, a 2-flute endmill designed for cutting aluminum might have a 37° helix angle, an 11° primary angle and a 15° radial rake angle. A 2-flute, general-purpose endmill, on the other hand, might incorporate a 30° helix angle and 7° angles for both the primary and radial rake. Each tool has two flutes, but few would notice the differences between them.

Yet, only one of the endmills would cut aluminum effectively. The general-purpose tool would fail prematurely if run at the same machining parameters as the aluminum-specific endmill.

Endmill manufacturers produce a flood of high-performance, application-specific endmills. They are made of HSS, M-42 cobalt or solid carbide, come coated or uncoated, and have from two to 16 flutes.

There are 2-flute endmills made to machine aluminum and 2-flute endmills for steel. Three- and 4-flute tools are available for a wide range of materials, as are 5- and 6-flute, general-purpose endmills. These cutters are suitable for steels and stainless steels, but not aluminum and nonferrous alloys.

Endmills with eight to 12 flutes are available, though they are less common. These endmills usually have large diameters—2" or greater—which allows them to accommodate additional flutes.

There are also specials with up to 16 flutes that remove metal like a circular burr. They are designed with minimal chip space for very fine finishing.

An application-specific design helps optimize an endmilling operation. But with so many choices, end users often ask questions about how to select a tool for a given application, including what is the appropriate number of flutes.* The workpiece material is the primary factor influencing this decision.

Material Issues

Although there are thousands of different metals and alloys, they generally fall into three groups: aluminum and nonferrous alloys; steels and stainless steels; and titanium and high-temperature alloys.

Aluminum and nonferrous alloys are considered the easiest to machine. Cutting speeds can be higher and feed rates heavier. Greater depths of cut are also possible with these materials, resulting in the formation of larger chips. Greater DOCs call for endmills with larger flute spaces.

When cutting aluminum and nonferrous alloys, 2- and 3-flute endmills generally work the best. These tools typically have a 50 to 55 percent core, meaning they have a 45 to 50 percent chip-evacuation space. This ample space helps prevent chip packing.

Steels and stainless steels are more difficult to machine than aluminum. They require tools running at significantly lower metal-removal rates to prevent excess heat from building up in the part and tool. The endmills used for steels and stainless don't require as much flute space for chip evacuation as those used for the aluminum/nonferrous group.

Many grades of steels and stainless steels are available. Two- and 3-flute endmills can effectively cut slots and pockets, or be applied when chip evacuation is an issue.

In peripheral and finish milling, end-

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A 5-flute endmill cuts pockets and slots and machines the periphery of this D-2 steel part.

**It's important to note that determining the optimal number of flutes for an endmilling operation is only one of the tool-geometry issues that must be addressed. The helix angle, core percentage, flute shape, primary relief angle and radial rake angle also significantly impact endmill performance.*

mills with four or more flutes are ideal because they enhance productivity and last longer. Four-flute endmills are likely to have a 65 percent core.

Titanium and high-temperature alloys can be some of the most difficult materials to machine, due to their high strength and toughness. They can also workharden.

Like steels, these materials must be machined at a lower mrr and a lighter DOC. A 4-flute tool with high-flute helix angles usually is a good choice.

Although chip packing is not a serious concern, chip evacuation is still extremely important. Effective chip evacuation helps remove heat and limits the recutting of chips. However, all the chip space in the world won't help if the heat can't escape from the cutting zone. If the chips hang up, soften or melt, they tend to smear on the tool's radial face and clearance angles—and milling stops.

Heat management, therefore, is critical when machining titanium and nickel-based alloys.

Application Considerations

The machinability of the workpiece material is key to endmill selection. But other application parameters, such as part shape, fixturing and tool paths, also figure into whether an endmill with two, three, four or more flutes is chosen.

Equally important is the specific type of endmilling operation to be performed.

Slot milling and pocket milling are difficult, due to complete or high tool-to-part contact. When slotting, the tool is fully engaged radially, making chip evacuation difficult. Tool selection is usually limited to 2- or 3-flute endmills because of the relatively large chip-evacuation space they provide. These styles also augment coolant flow to the cutting edge.

Another factor when slotting or pocketing is how the endmill engages the workpiece. Two-flute endmills are center-cutting, a feature that allows them to plunge or ramp into the part.

There are more choices available when choosing an endmill for peripheral milling than for slotting or pocketing. Endmills with more than two or three flutes can be selected for peripheral milling because chip evacuation is less of a concern.

Still, if heavy axial and radial DOCs—greater than 50 percent of the tool diameter—are taken, chip packing and evacuation problems may occur. For heavy peripheral cuts, 3- and 4-flute endmills are effective.

A 3-flute endmill slots a 6061 T-6 aluminum assembly.

For light finishing cuts and cuts where less than 50 percent of the tool is engaged radially, a 5- or 6-flute endmill would be a good choice. Such a tool would provide continuous tool-to-part contact and impart an excellent surface finish.

Application-Driven

Successful endmilling depends on using a tool with the right geometry and the correct number of flutes, as well as running the tool at the proper speed and feed. For example, if the specifications for a titanium part dictate pocketing, the correct tool would be a high-performance, 3-flute endmill. But if the same part requires peripheral finish milling, a 5-flute tool would be the proper choice.

As with any metalcutting operation, endmill selection is driven by the specific application.

To further illustrate the point, consider slotted and pocketed aircraft parts. They require tools with geometries and coatings designed for cutting titanium. They could have three or four flutes, and they should have heavy cores and be strong enough for titanium.

The milling process is rarely straightforward. It's necessary to understand the implications and subtleties of the different endmill styles. And, given the many choices available, end users must understand how different coatings, number of flutes, rake angles and relief angles would affect their application.

Furthermore, precision metalcutting encompasses every element in the machining system, which includes the machine tool, toolholder, cutting fluid, fixturing and workpiece. The entire process must be understood if an endmilling operation is going to be successful. Picking a tool with the right number of flutes for an application won't ensure success if, for example, the wrong toolholder is selected.

About the Author

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