# Understanding Circle-Segment Milling Tools

The circle-segment cutter represents a class of milling tool in which the CAM software is key for using the tool effectively. Cutting profiles presented at the proper angles realize cycle time reductions in contoured workpieces such as molds. A CAM company engineer discusses the role of this tooling.

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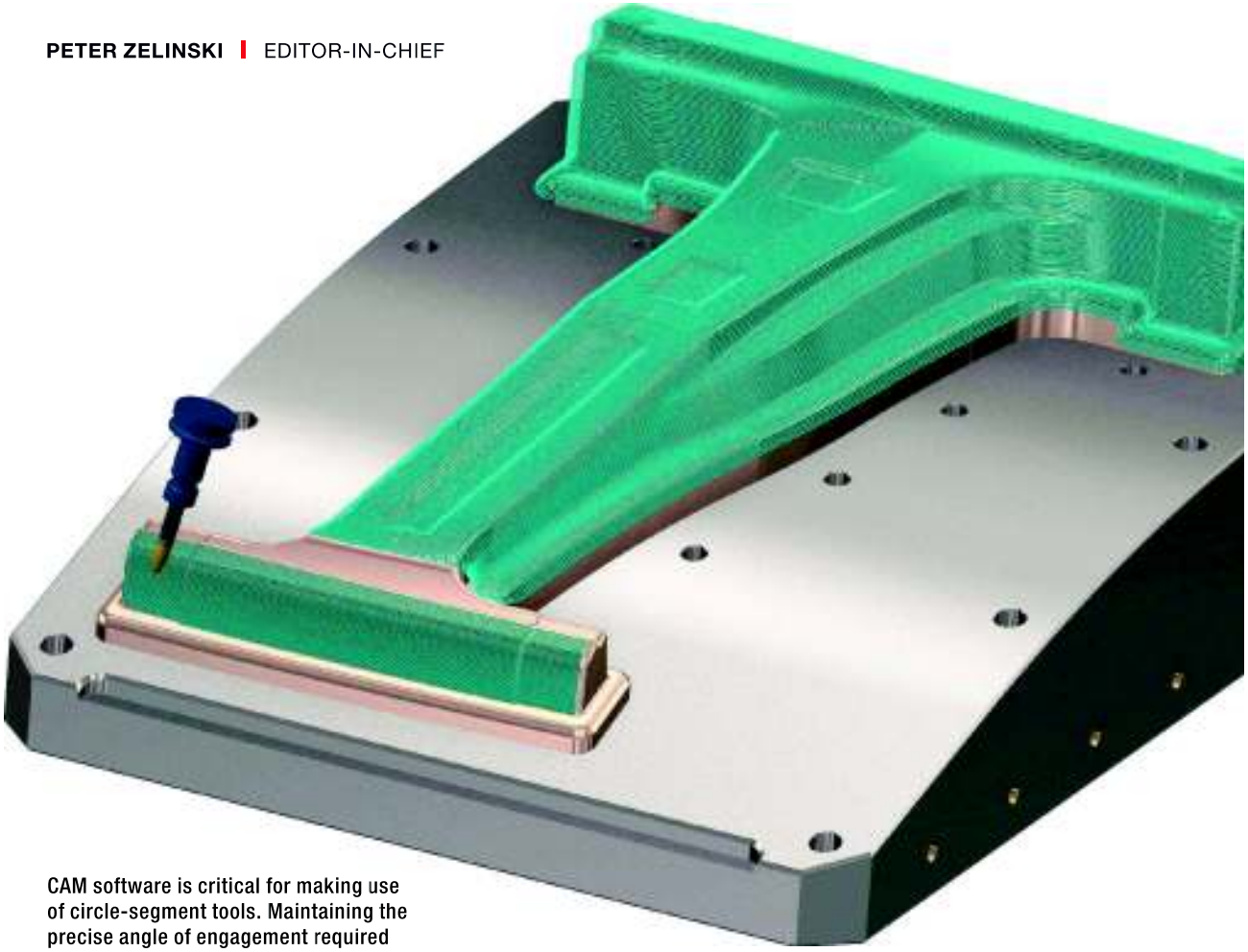


CAM software is critical for making use of circle-segment tools. Maintaining the precise angle of engagement required demands tool paths tailored to each of the different circle-segment tool types.

Here are drawings of the profiles of four circle-segment tool types. Seen here from left to right are barrel, lens, taper and oval forms.

Over time, machine tool motion has become more intricate. In particular, precise control of five-axis machining centers allows for elaborate tool paths. Also over time, CAM software has become more sophisticated, increasing the ease and effectiveness with which complex machines can be programmed.

But cutting tool forms have remained simple. Standard milling tools come in basic forms that would have been recognizable even well before the age of programmable machining. We take this for granted. However, do cutting tools require simple shapes? As it turns out, they do not. Complex machines can mill complex forms using complex tools—and this last item is the piece that has now arrived and is beginning to find its place.

Cutting tool maker Emuge offers a line of circle-segment milling tools—so-called "barrel cutters" and others—that offer profiles engineered to effectively finish-mill various contoured workpiece surfaces, notably in die/mold machining. A challenge that makes these tools distinctive is the demand they make of the tool paths. Using these tools effectively requires tool paths that keep the tool's cutting profile engaged with the surface of the part at a precise angle proper for that tool design. To meet this need, Emuge partnered with CAM software providers to develop programming algorithms able to realize the full promise of this tooling.

One such partner is CNC Software Inc., developer of Mastercam. Application Engineer Jesse Trinque is one of the company's team members who has been involved in developing Mastercam capabilities tailored to circle-segment tools, and he has worked directly with shops applying this tooling. He recently offered his perspective on the importance he sees for this relatively new type of milling tool, and the corresponding importance of the cutting tool and the CAM software increasingly working as a unified system.

"In the past, CAM actually hasn't modeled cutting tools as tools," he says. It didn't need to. Cutting tool shapes were so simple—a cylinder for an end mill, or a cylinder with a hemispherical tip for a ballnose end mill—that just these simple geometric solids were sufficient to accurately represent the tools in CAM. Circle-segment tools change this, he says, because they require a non-simple cutting tool form to be precisely realized and precisely manipulated with respect to a workpiece form that is also not simple. This is the task to which CAM developers have been rising in equipping their software to make use of these tools.

The payoff is nothing less than vastly reduced finish-milling times for workpieces featuring geometric contours. A circle-segment tool accomplishes the same thing as a ballnose tool to the extent of using a contoured edge to mill along a contoured surface. However, a ballnose tool features a cutting-edge radius that is only as large as the radius of the tool. By contrast, a circle-segment tool such as a barrel or oval cutter manages to deliver a large-radius milling profile using a tool that remains slender. Other profile types in Emuge's line include lens and taper. (See drawings above and photos on the next page.)

The advantage of the ballnose tool is that this classic tool type is agnostic on engagement angle. At whatever angle the tool is used, the tip still presents the same circular profile. The ballnose's disadvantage, Mr. Trinque says, is cycle time. The tool requires a small stepover increment to machine a smooth surface, leading to long cycle times when the surface is large. Circle-segment tools can bring large stepovers and short cycle times to the same surfaces, but these tools have

Photos of the different circle-segment tool types. The lens tool (third from top) has its large-radius cutting edge along the tool tip.

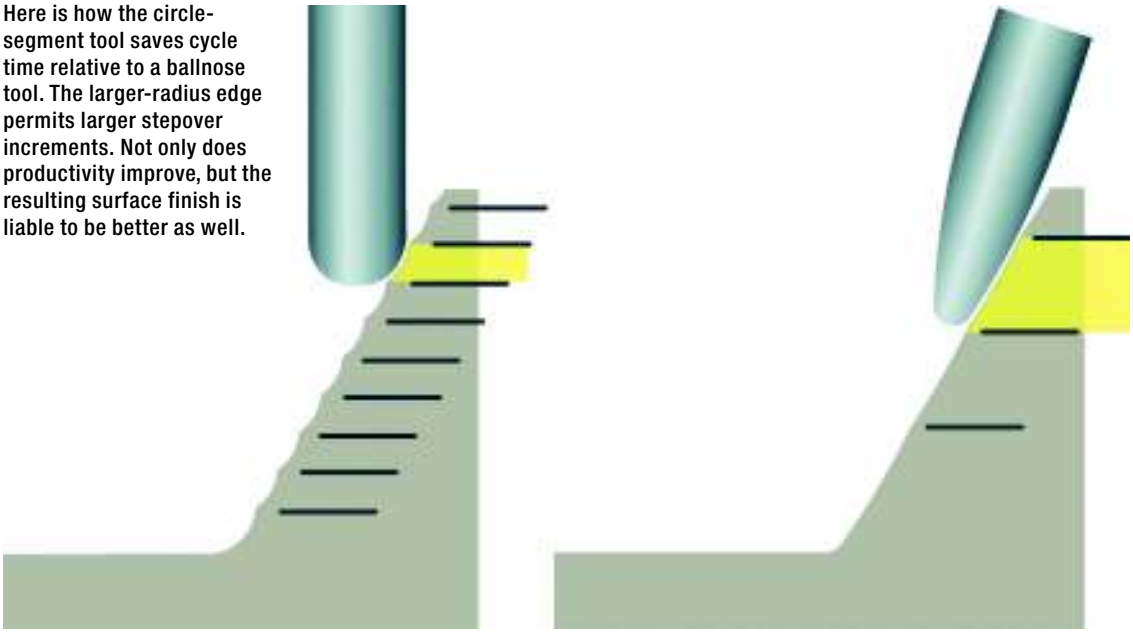
to be held at just the correct angle so that the large-radius profile comes into play.

What angle? Mr. Trinque says the tool with an oval form is limited to a 15-degree range of motion at which the tool is effective. The taper-form tool is far more limited than this; its angle of engagement cannot vary by more than 0.1 degree. The ballnose, by contrast, is effectively unlimited in its range of motion. This is why ballnose tools are routinely used on even basic machining centers, but circle-segment tools are applied almost entirely on five-axis machines.

He says the chief application in which a circle-segment tool thrives is milling a contoured surface that covers a large, relatively open area of the part. This might mean machining the bottom of a mold cavity with a lens tool or machining the sides of a mold core with a taper or oval tool. In either case, a finishing operation that might have taken several hours with a ballnose tool could be reduced to less than an hour with strategic application of various circle-segment cutters.

Mold and die machining is not the only application, he says. Aerospace parts with large swept surfaces are also candidates, as

Here is how the circle-segment tool saves cycle time relative to a ballnose tool. The larger-radius edge permits larger stepover increments. Not only does productivity improve, but the resulting surface finish is liable to be better as well.



**Circle-segment tools all but need five-axis machines, particularly in machining of die and mold forms, to keep them cutting at the angles they require. These tools realize the promise made possible through sophisticated machine motion plus sophisticated programming.**

are medical implants. Both of these latter types of parts have the advantage that they likely already are being produced on five-axis machines. "We recently assisted a company machining a titanium knee component," he says. "It was already five-axis, but the finish-milling cycle was 70 minutes. Circle-segment tooling reduced this to 10 minutes and delivered an even better surface."

Ballnose tools remain important. Frequently, complex parts have hard-to-access features for which only a ballnose can do the machining at the restricted angle that the part itself makes possible. Indeed, Mr. Trinque says this point suggests one of the main challenges and mindset changes he sees related to the adoption of the newer tooling.

"Companies that have heard of the effectiveness of circle-segment tools often want to apply them to everything," he says, but these tools have limitations. In general, they are no good for roughing, he points out. Each of the specific tools has advantages and an application range of its own. Their different uses potentially expand the options available to the programmer, but in the same way, they change the importance of the decisions the programmer makes in realizing a productive process. "In the past, you might have used just one tool to finish a cavity," he says. "Now, including circle-segment tools might mean you think about that same cavity in terms of four different tool paths for four different tools that each do some different region of that cavity productively."

Increasingly, this is how die/mold programmers will need to think, Mr. Trinque says. In his view, cutting tools offering complex profiles are the future. In machining contoured forms, they are the final piece bringing together the sophistication CAM software can realize with the complexity five-axis machining can achieve. Other cutting tool makers are also introducing tools with interesting and useful forms, he says; CAM software can no longer account for tools just as simple shapes. Today, Mastercam deploys circle-segment tools using libraries of tool models tailored to these unusual forms, he says, but this is just an interim step. Under development now is capability that will enable the users of the software to input their own tool profiles, thus equipping the software to make use of whatever is the latest tool form the user needs for CAM to put to use.

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