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As Easy as X, Y, Z

Helical interpolation is an effective option when opening previously produced holes or machining large new ones.

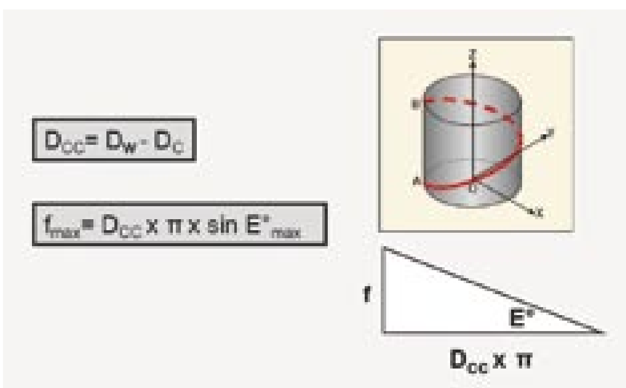
All images: Walter USA

A helical mill is just one of the standard tools available for performing helical interpolation.

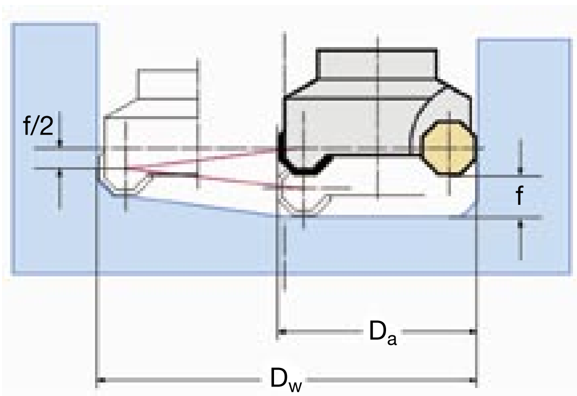
The old saying goes that you can't fit a square peg into a round hole. Likewise, standard drills only make holes that approach their diameter size, i.e. one drill size for one hole size. However, in production holemaking, you can turn that old saying on its head by drilling a hole that's up to twice the diameter of the cutting tool. That feat is accomplished by helical interpolation—a technique to make holes of various sizes up to 8 diameters deep with a single milling cutter. Depending on the machine's CNC and coordinate system, helical interpolation involves the X- and Y-axis performing the circular movement while the Z-axis handles the helical movement that ramps the tool into the workpiece.

One Tool for Many Sizes

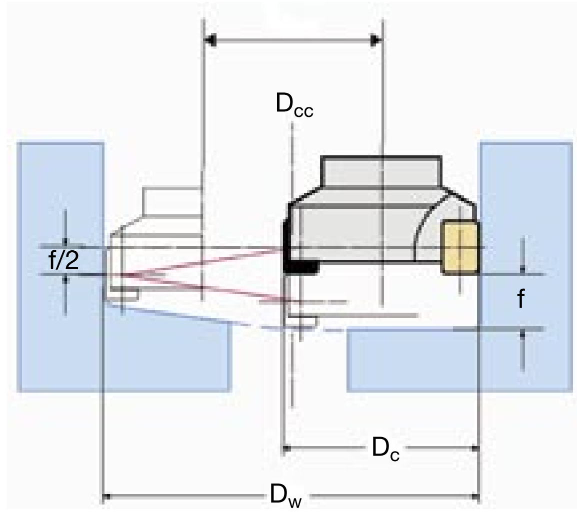
The higher stiffness and horsepower rating of a horizontal machining center generally provides better performance for helical, or circular, interpolation. But the process can also be performed with a vertical machining



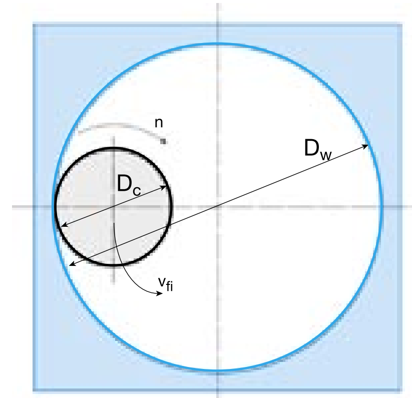
Development of an involute.



Helical interpolation when machining from a solid workpiece.



Helical interpolation when opening a premachined hole.



$$V_{fi} = \left[1 - \frac{D_c}{D_w}\right] \times n \times f_z \times Z$$

Machining an internal contour via helical interpolation.

center to create holes of varying sizes in solid workpieces or by opening previously produced holes using a single tool. Therefore, helical interpolation eliminates the need to have many different drills—one for each diameter-size hole produced.

With this machining strategy, even low-horsepower machines, around 15 hp or less, are able to create bore dimensions unattainable with standard drills. This is because such machines lack the horsepower, torque and, especially, thrust to drill a hole in one step.

Although CAM software is not required to perform helical interpolation, it's more convenient to program the machine using a standard CAM package. In addition, most CNCs provide preprogrammed cycles for helical interpolation.

Helical interpolation does not require special tools. Manufacturers can apply a variety of standard milling tools in helical interpolation, depending on the hole specifications. These tools include shoulder mills, octagon mills, button cutters and high-feed milling cutters. Another standard option is a helical mill, where the insert rows form a helix.

Hole Variations

As with other holemaking processes, the success of helical interpolation depends on knowing the workpiece and the final part's specifications. This includes the workpiece's basic shape, its dimensions, and the part's tolerances and surface finish requirements. The major consideration is whether the hole will be helical-interpolated from a solid workpiece or an already premachined, cast or forged hole.

For holemaking from a solid workpiece, the tool's maximum ramping capability is the main criteria. The higher the ramping capability, the faster the orbital helix.

In comparison, when helical interpolating a premachined, cast or forged hole, it is more important to have the maximum axial pitch per orbit of the tool in conjunction with the optimal ratio of tool diameter to bore diameter. When opening a premachined hole, the maximum axial pitch per orbit should be equal to the length of the main cutting edge.

After selecting the tool and machining strategy for a workpiece, an end user must determine cutting parameters. Consult your tool supplier or reference a tool catalog's technical section for starting-point speed and feed recommendations. Compared to linear machining, the parameters for helical interpolation vary greatly.

Key

a_p	DOC (in.)
a_e	WOC (in.)
D_c	cutting diameter (in.)
D_{cc}	circular interpolation of tool's center
D_w	workpiece diameter (in.)
E°	ramping angle
f	feed per orbit (in.)
f_z	feed rate per tooth (in.)
n	rpm
v_c	cutting speed (sfm)
v_f	feed rate (ipm)
v_{fi}	feed rate of tool center line (ipm)

Effective Chip Load

Because the center of the tool travels at a different feed rate than at the periphery, where the inserts are located, during helical interpolation the cutting edge can become overloaded. Therefore, adjust feed per tooth values to ensure the correct chip thickness. The feed per tooth will be roughly 50 percent less than when machining in a linear path, although the metal-removal rate stays the same.

$$n = \frac{v_c \times 12}{D_c \times \pi} \text{ [rpm]}$$

Number of revolutions

$$v_c = \frac{D_c \times \pi \times n}{12} \text{ [ft/min]}$$

Cutting speed

$$v_f = f_z \times Z \times n \text{ [in/min]}$$

Feed rate

$$f_z = \frac{v_f}{Z \times n} \text{ [in]}$$

Feed per tooth

The tool spindle adapter, such as CAT 40, CAT 50, HSK 63 or HSK 100, is one indicator of a machine's strength and helps determine the maximum mrr. Achieving maximum mrr is the most important goal. It requires optimizing the number of cubic inches of metal removal based on the machine's horsepower, specific workpiece material and average chip thickness.

Helical interpolation is an effective holemaking option when opening big holes in cast iron workpieces and large structures where making short chips is desirable. The process produces faster cycle times, reduces the number of tools required and uses standard tools—although special milling cutters are often applied for hole diameters outside the standard drill-diameter range.

Producing holes via helical interpolation is appropriate for any parts requiring tight tolerances, and its use is growing as more end users seek to be more productive with lower cost machines. It is especially beneficial when machining materials that tend to workharden. In addition, strategies for machining rectangular pockets by performing elliptical helical interpolation in heat-resistant alloys, stainless steel and titanium for the aerospace industry promise to dramatically boost productivity by reducing cycle time. △

About the Author

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