

How 5-Axis Milling

Changes the Machining Paradigm

Impro

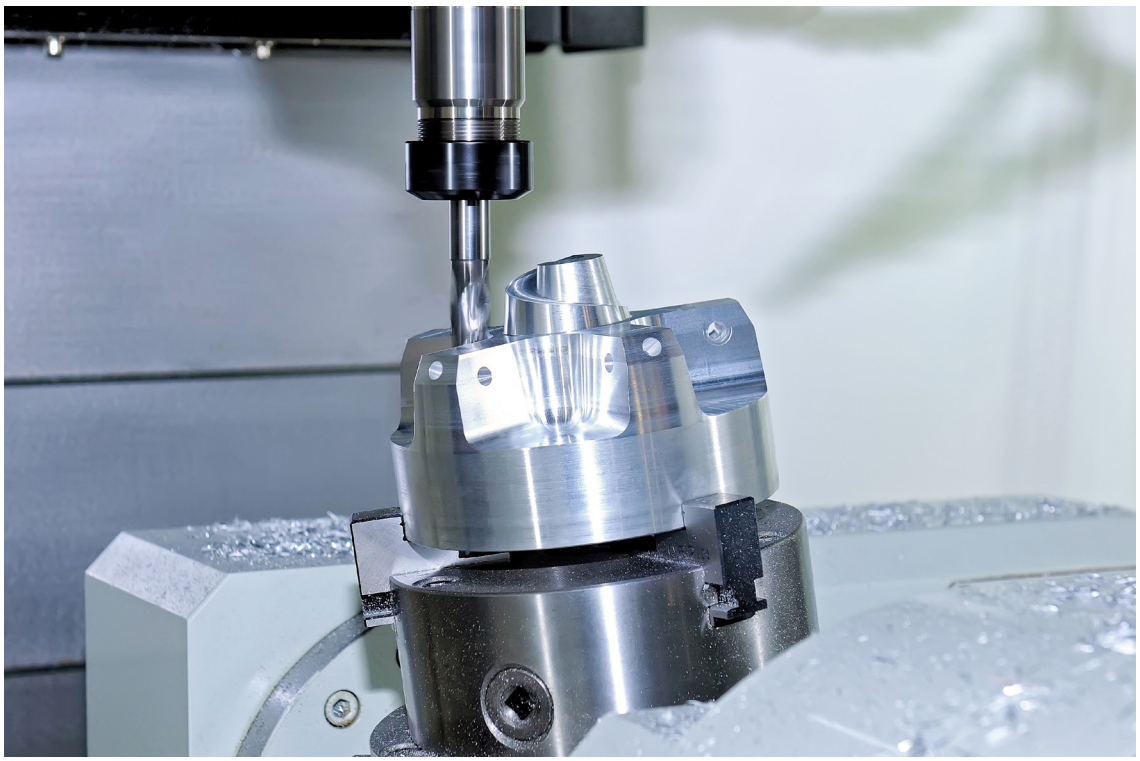
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Machining has always imposed constraints on part design, especially when cost is a consideration. Flat and square surfaces and perpendicular holes and bores mean fewer setups, higher accuracy and better finishes. Unfortunately though, this limits what the product engineering team can do to maximize performance and functionality.

In recent years 5-axis milling has completely changed this paradigm. With this powerful new capability a machine shop can produce almost any geometry the product team needs.



This eBook explains the new capabilities 5-axis milling provides and how they benefit product design. After introducing the technology it explains how this differs from traditional 3-axis methods, and the advantages that result. Individual sections address:

- *The limits of conventional machining*
- *New capabilities enabled by 5-axis milling*
- *The quality impact*
- *What 5-axis milling means*
- *The impact on part design*
- *The cost impact*

The Limits of Conventional Machining

At a fundamental level, there are only two types of machining. Either the workpiece turns and the cutting tool comes into contact with it, which produces a cylindrical shape, or the workpiece is fixed and a rotating cutter removes material.

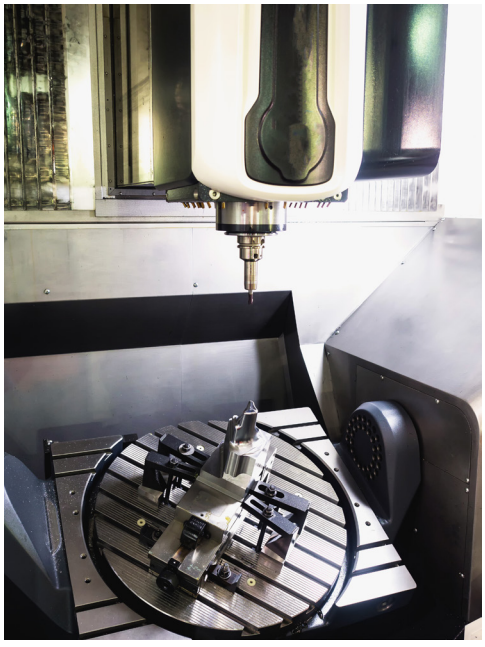
Machining a fixed workpiece with a rotating cutter is milling. In milling a casting or billet of metal is clamped to a table and moved under the cutter. This produces a smooth, flat surface. To machine a second surface at 90° to the first, the workpiece is unclamped, reoriented, and clamped again. Machining multiple surfaces requires multiple operations with the part being repositioned each time.

Most vertical milling machines can move the cutter up and down. This, in conjunction with table movement in X and Y directions enables milling of features like pockets. However, milling anything other than orthogonal surfaces requires carefully positioning and clamping the workpiece at an angle.

Setup is non-productive time that reduces the potential income from performing milling work. In addition, it creates opportunities for a loss of accuracy. Possible causes are tool offset errors and poor clamping to the work table or machine bed. Furthermore, increasing the extension of the tool or using the full range of Z-axis motion tends to worsen surface finish and requires lower cutting forces by reducing depth of cut.

What 5-Axis Milling Means

When facing a milling machine, left-right movement of the table is the X-axis, forwards-backwards movement is Y-axis and up-down is the Z. Adding two rotational axes, usually rotation around x and Y axes, provides a total of five.



These additional axes can be provided in two ways. Either the machine headstock and spindle, (the part holding the cutting tool), rotates in two axes, or two rotary tables on the machine bed hold the workpiece and turn. In general, rotary tables have a greater range of motion than a tilting/rotating machine spindle. Machines of this type also tend to be less expensive.

The additional axes increase the complexity of part programming. Only with the emergence of more powerful CNC machine controllers and advanced CAD/CAM software packages has 5-axis milling become practical.

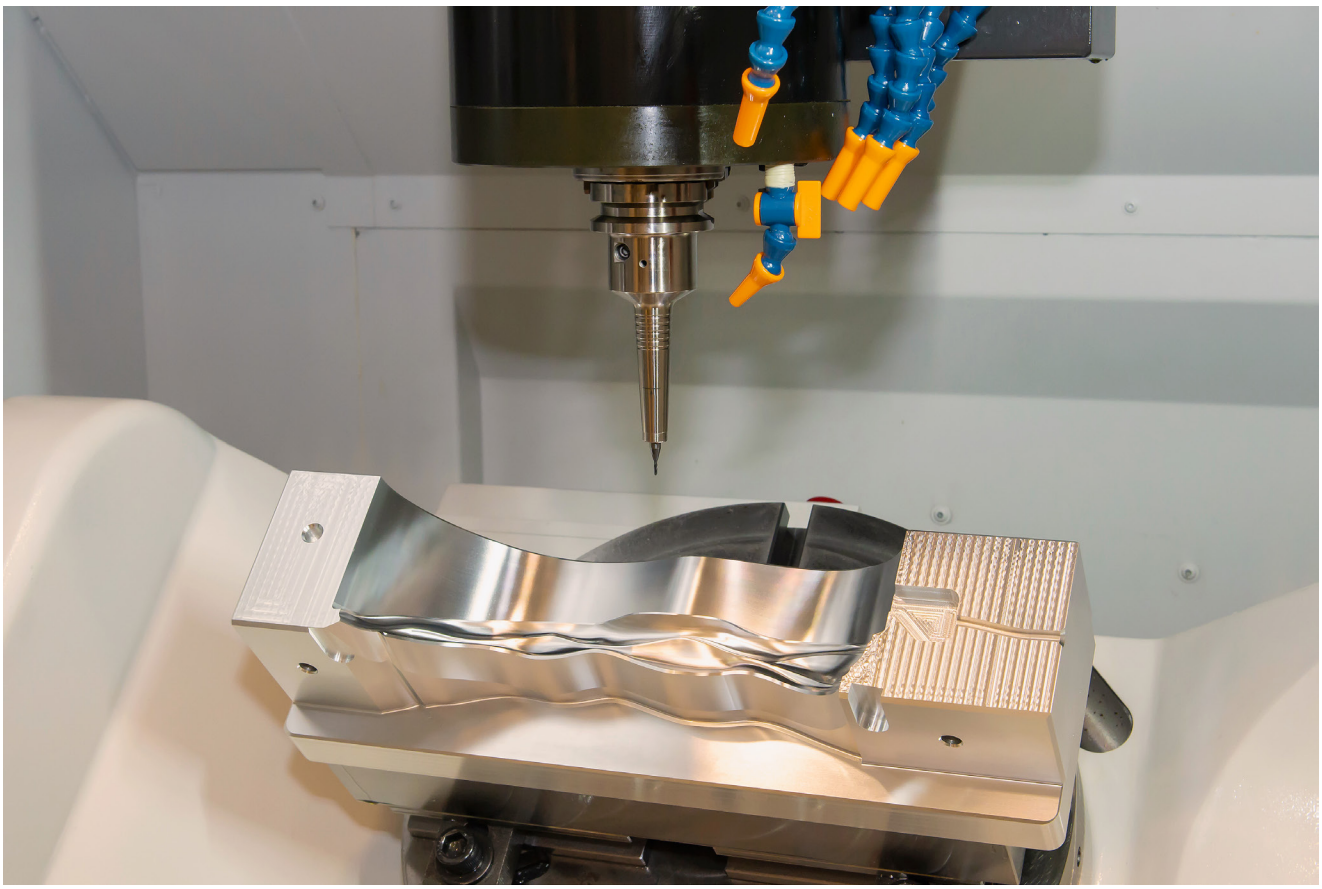


New Capabilities Enabled by 5-Axis Milling

Adding rotation axes lets the CNC machine controller change the orientation of the part to the cutting tool. This can be done between cuts, or while cutting.

Rotating the workpiece between cuts lets the machine expose other surfaces to the cutter, and at any angle. For example, after milling a flat surface, rotation of 45° allows milling of a second flat surface at this angle to the first. It could also provide access to mill a groove or undercut feature in an area not otherwise accessible. Notice though that the milled surfaces are still flat.

Changing the orientation of the workpiece to the cutting while in-cut enables machining of contoured surfaces. This is something that might be done when machining mold tools. Rather than making a series of cuts that leave small steps on the surface, the cutter axis is kept at 90° to the workpiece surface, producing a smooth yet curved form.



The Quality Impact

Milling on a 5-axis machine improves workpiece accuracy and surface finish.

Accuracy, in terms of the relationship of features to one another, is higher because the part doesn't undergo multiple setups. Instead, every feature is produced in one setup. Accuracy is further improved by using shorter tools that extend less from the toolholder and so don't suffer as much deflection.

Surface finish is improved in two ways. First, shorter tools that protrude less suffer less vibration and runout. Second, maintaining the cutting tool axis at 90° to the surface results in a better finish.

The Cost Impact

The increased complexity of a 5-axis CNC machine tool raises its purchase price and the hourly running costs. However, depending on the design of the parts being machined, there are still significant cost savings to be had. These stem from the ability to do more machining in a single setup. This:

- Increases machine availability - a machine tool is not available during setup
- Reduces, even avoids, the need for additional machine tools
- Reduces setup hours
- Saves on handling
- Can reduce inventory - no movement of batches between machines
- Reduces waste - fewer parts used for setup and fewer quality issues

Additional savings result from the opportunity for component consolidation. (See below.)

It's important to note though, that cost savings are dependent on the design of the part being machined. If it's possible to produce the required features in a single operation on a standard CNC milling machine, it should be machined this way. Putting a simple part on a 5-axis machine is unlikely to yield enough savings to compensate for the higher hourly rate.

The Impact on Part Design

5-axis milling frees the design or engineering team from thinking in terms of orthogonal shapes and surfaces. No longer is there a severe cost penalty for putting features at angles to one another. Now, if part function requires various mounting faces at compound angles, it's possible to produce them, in a single setup.

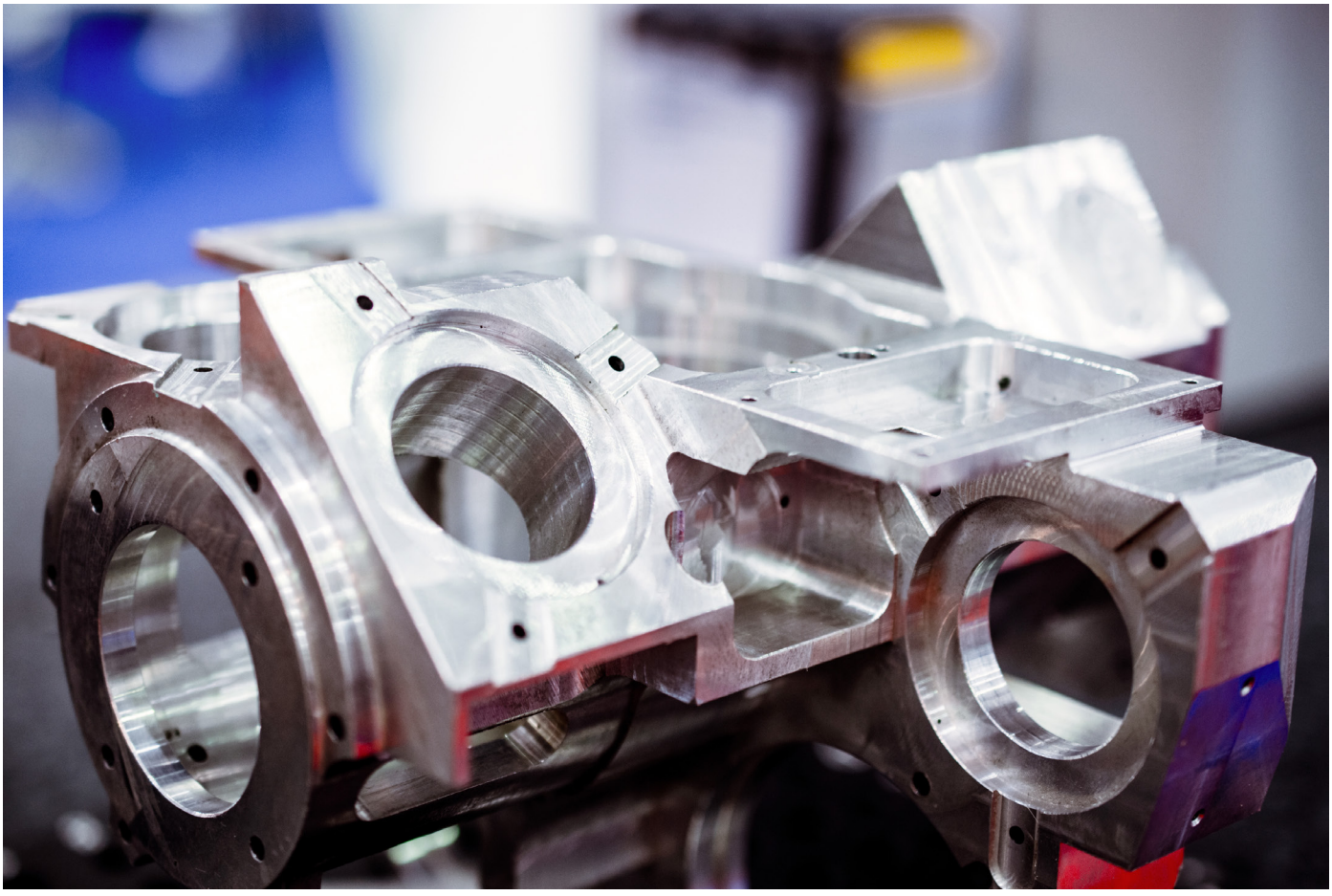


This capability also increases opportunities for part consolidation. Instead of joining two parts with fasteners or by welding to create complex geometries, 5-axis machining opens the door to more complex castings with features at varying angles to one another.

The ability to contour opens up a host of additional new design possibilities. Milling of mold tools was mentioned previously, but contouring also applies to a wide range of forming tools. Contoured surfaces can improve fluid flow in pumps, valves and other hydraulic components, and are essential in medical implants.

Advanced Precision Machining Capabilities

Impro has invested in a wide range of precision machining capabilities, and this includes 5-axis milling. On geometrically complex workpieces 5-axis milling can lower overall cost while improving quality. Perhaps of greater interest to the design team though, 5-axis milling provides capabilities, particularly the ability to mill contoured surfaces, not otherwise available.



If you're exploring manufacturing options for machined parts, 5-axis milling may open up design options you haven't considered. If you'd like to learn more, please contact us to discuss your designs.

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