Maximizing Machine Efficiencies

Ultra-High Performance Toolpath (UHPT) Technology Can Transform U.S. Manufacturing

By Alesa Lightbourne, Ph.D.

Since the dawn of machining, the manufacturing industry has looked for ways to squeeze greater efficiencies out of existing equipment, materials and labor. Computer-aided manufacturing (CAM) and computer numerical controlled (CNC) machining were huge steps in the right direction several decades ago. But in recent years, we have seen only small, incremental improvements in machining productivity. This is because research focused primarily on computerization to streamline toolpath generation, and on expensive toolpath "optimizer" software, slowing feedrates at corners to reduce stress on tools. Nearly all innovations assumed a parallel-offset toolpath used for roughing out parts – not realizing that this was the real bottleneck.

A breakthrough technology changes all this. Ultra-high performance toolpath (UHPT) software improves the way that tools cut their way through material, using high-speed continuous tangent motion rather than sharp, interrupted movements. Field applications prove that UHPT technology can safely double machine output, extend tool life, and create a much more productive competitive manufacturing enterprise in the global marketplace.

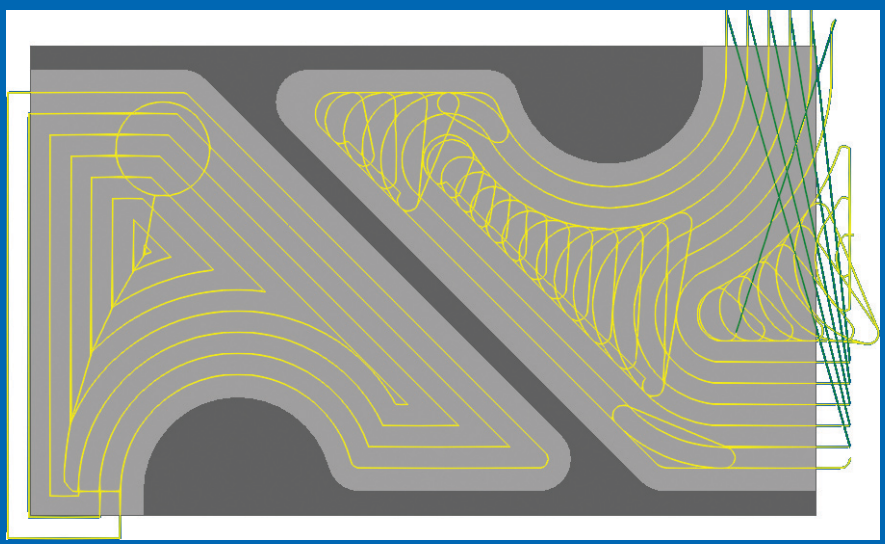

Figure 1: A standard toolpath (left) makes parallel cuts through material, requiring numerous stops and starts. UHPT technology (right) designs toolpath cuts in continuous motion, doubling machine efficiency.

Avoiding the corners and stop signs

Imagine driving through a neighborhood without arterial streets. At each corner, you must slow down or stop at a stop sign, make a turn, and proceed for another block, always encountering changing traffic conditions. Or think of a rural road that skirts the perimeters of various farmers' fields, filled with tractors and trucks. Slow down, pass, stop, turn, go, sharp turn, go. Slow down. It's maddeningly inefficient.

That's how basic toolpaths drive today's CNC machines. Modeled on manual methodology, existing toolpaths are derived from the geometry being machined. They start with the material boundary and keep

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stepping in, following the shape of the material, regardless of efficiencies, until the path collapses on itself. In other words, the tools follow a path regardless of the amount of material they encounter. They slow down, sometimes stop, change direction, and cut again, sometimes encountering excessive material, other times little material. This is very hard on both machines and tools.

Now return to the neighborhood, and imagine it redesigned on a circuitous route, with carefully banked roundabouts and smooth curves instead of corners and stop signs. The amount of traffic is steady; it almost never slows down and never comes to a halt. You drive at a high average speed until you reach your destination. Yes, you might travel a bit further in distance. But the time you save, the fuel efficiency, and the reduced wear and tear on your car make the circuitous design well worthwhile. This is the underlying concept behind UHPT technology.

How it works

UHPT technology works on any shape, open or closed, with any number of features, and integrates with any CAM system. It plans the toolpath based on abilities designed into the machine and cutting tools. By taking advantage of the capabilities of modern machining hardware and avoiding sharp directional changes, it generates toolpaths that assure the machines and cutting tools are used at peak efficiency given existing conditions.

What Is UHPT Technology?

A high-performance rough-milling toolpath engine with:

- **Circuitous paths for constant motion**
- **Sophisticated algorithms for any open-shape or pocket geometry**
- **Seamless interface with any CAM system and any material**
- **Up to 100% stepover with no uncut material**
- **Slot- and side-milling options**

Currently a 2.5-axis product, UHPT software is ideal for prismatic parts. It easily cuts pockets, steps, slots, channels and other shapes, and can handle an unlimited number of material and part boundaries and islands. It can be used with any cutting style and material, including the hardest metals.

Traditional toolpath technology forces machinists to accommodate worst-case machining conditions to prevent damaging the spindle and wearing out the cutting tool. Abrupt changes in the amount of material being encountered put excessive force on the part and machine. So programmers and machinists select slower feeds and speeds, or make shallower cuts. The unfortunate result is longer cycle times, higher tool costs and lost productivity.

UHPT technology, on the other hand, allows programmers to use the most appropriate cutting styles and optimum feeds and speeds. This is possible because UHPT software designs toolpaths with no abrupt changes in direction or to the volume of material encountered; the load on the cutting tools and spindle never exceeds user-programmed limits. Consequently, machines run smoothly and tools run cooler, even at much higher speeds and feeds, extending tool and machine life.

Optimized cutting capabilities

Another major difference over existing technologies lies in flexibility. UHPT software actually compares the speed between slotting or side milling an area under given conditions and selects the fastest or most efficient approach. In general, UHPT technology minimizes the amount of slot milling because of the excessive amount of material encountered. But when slot milling is the optimum solution, UHPT technology reduces the axial depth of the cut and slows down the feedrate, reducing the amount of material encountered and maintaining a consistent load on the tool and spindle. If desired, the programmer can specify only side milling, and eliminate any slot milling to avoid burying the tool. This is especially useful in very hard metals.

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Jake Kopveiler, CNC Programmer, Performance Tool and Die

The "sweet zone"

For every unique combination of machine, cutting tool and material, a "sweet zone" exists, where an ideal combination of feedrate, spindle speed, cut depth and cut width maximizes material removal while obtaining acceptable tool life. Just as cars get better mileage on the freeway compared with stop-and-go traffic, so do CNC machines and cutting tools function better, last longer and require less maintenance when they run in their sweet zone.

Typical toolpaths frequently encounter "not-so-sweet zones," since the amount of material exposed to the cutting tool fluctuates. NC programmers compensate for the instances where the tool load is excessive by using less aggressive cutting parameters (feedrate, spindle speed, cut depth and cut width) throughout the toolpath. While there are typically hundreds of instances where the cutting tool encounters excess amounts of material in a typical toolpath, the duration of each is brief, and together they comprise just a small percentage of the overall toolpath length. The unfortunate fallout of this is that the parameters in use are far too conservative for the majority of the toolpath; the tail is wagging the dog. Therefore, machine tools and cutting tools never get to run as they are designed and engineered, namely in their sweet zones. They are either being abused or underutilized. This results in machine tools and cutting tools being utilized to only a fraction of their capability.

Reports from early adopters of UHPT technology demonstrate reduced cycle times by up to 70%; extended tool and machine life of up to 45%; and 200% improvements in efficiencies over all other 2-axis rough-milling toolpaths

Conversely, UHPT software designs toolpaths that are free of the instances of excessive tool load, regardless of the shape of the geometry, so parameter compromises are not necessary. This enables machine tools and cutting tools to operate under near ideal conditions, and to perform up to their true capabilities.

Advantages over HSM

Several advances in machining technology claimed to resolve speed and output issues, but have fallen short. For instance, high-speed machining (HSM) has been touted as a solution for maximizing machine efficiency. HSM uses shallow axial cut depths and tangential motions, which can reduce cycle times in some cases. But HSM techniques cannot be used efficiently for all kinds of parts. Also, it requires CNC machines with very high spindle speeds and feedrate capability, along with sophisticated controller capabilities such as look-ahead for hundreds or thousands of blocks of code, an unaffordable proposition for most shops. So high speed machining represents only a partial solution to the industry's needs.

Part applicability and cost are not issues for UHPT software, which works on any part geometry and with any machine. UHP technology therefore makes every machine a "high-speed machine."

Mathematical ingenuity

The UHPT concept was developed by Glenn Coleman and Evan Sherbrooke, Ph.D. Coleman is a toolpath scientist and inventor of several toolpath generation methods and toolpath algorithms that significantly reduce both programming time and machining time. Two patents have been awarded to these inventions, and patents are pending on others. Dr. Sherbrooke is an internationally recognized expert in engineering, computational geometry, solid modeling and high-level algorithms, including the Medial Axis, The Medial Axis Transform, shape recognition, and graph theory.

Coleman and Sherbrooke realized that existing toolpath strategies were flawed and did not optimize the capabilities of modern CNC

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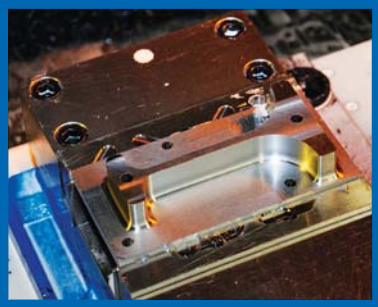
machines. Together, they constructed a sophisticated mathematical formula that resulted in the UHP toolpath technology breakthrough. Their firm, Celeritive Technologies, Inc. of Cave Creek, AZ, is currently the only provider of UHP toolpath technology, offered under the brand name of VoluMill™. Celeritive has applied for a patent on this technology.

Efficiency doubled in field test

PTD Manufacturing, a metal stamping and fabricating facility in Detroit Lakes, MN, recently adopted UHP toolpath software in its tooling department. The software is configured as an add-on module, working seamlessly within GibbsCAM. PTD now uses the technology to program 3- and 5-axis vertical mills. After just a month in operation, PTD confirmed significant improvements in tool life, scrap and total efficiencies.

Before switching to UHP toolpath technology, PTD Manufacturing roughed out pockets using a large inserted tool taking 0.1 to 0.2 axial steps. Then pockets were finished with a solid-carbide endmill. Today, PTD uses a much smaller solid carbide tool, taking full-depth axial cuts, with a 0.02" to 0.05" peripheral cut at approximately five to ten times the feedrate and RPM.

In PTD's toolroom, every block is different from the last, so fixturing and workholding tended to be a problem, especially with its 5-axis mill. UHP toolpaths exert a smaller amount of cutting pressure than previous methods. PTD has therefore been able to reduce the rigidity of its set-ups, also reducing the number of set-ups per block, permitting a move to more universal fixturing.



In a recent field application, PTD Manufacturing used UHPT technology to cut out this part, more than doubling machining efficiencies over its previous solution and illustrating the large quantities of metal that can be easily and quickly removed.

The most dramatic improvement to date has come from PTD using UHP toolpath technology to mill a large pedestal punch from A2 toolsteel. Previously, it took 22:36 minutes to run the punch with a 3" inserted shell mill. Now it takes just 7:20 minutes with a ½" carbide ball endmill – a 208 percent increase in efficiency. Throughout the shop, PTD estimates that total machining time has been reduced by about 40 percent, with commensurate reductions in material costs.

Jake Kopveiler, CNC programmer at PTD Manufacturing, is a firm believer in the new technology. "There's no comparison between our old and new systems. UHPT technology creates toolpath cuts much more intelligently, with more aggressive parameters. It has optimized our machine and cutting tool capabilities like nothing I've ever seen. The improved cycle time speaks for itself."

Industry implications

The potential impact of UHPT engineering is staggering. Consider the very real possibility that every manufacturing facility in the United States could double its machining output using existing hardware and CAD/CAM technology, merely by adopting an inexpensive platform-neutral software program. The resulting cost efficiencies could more than offset current pressures to move manufacturing overseas, helping to improve national employment and economic conditions. Furthermore, by reducing both material and utility requirements, UHPT technology represents a truly "green" solution for the industry as a whole.

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