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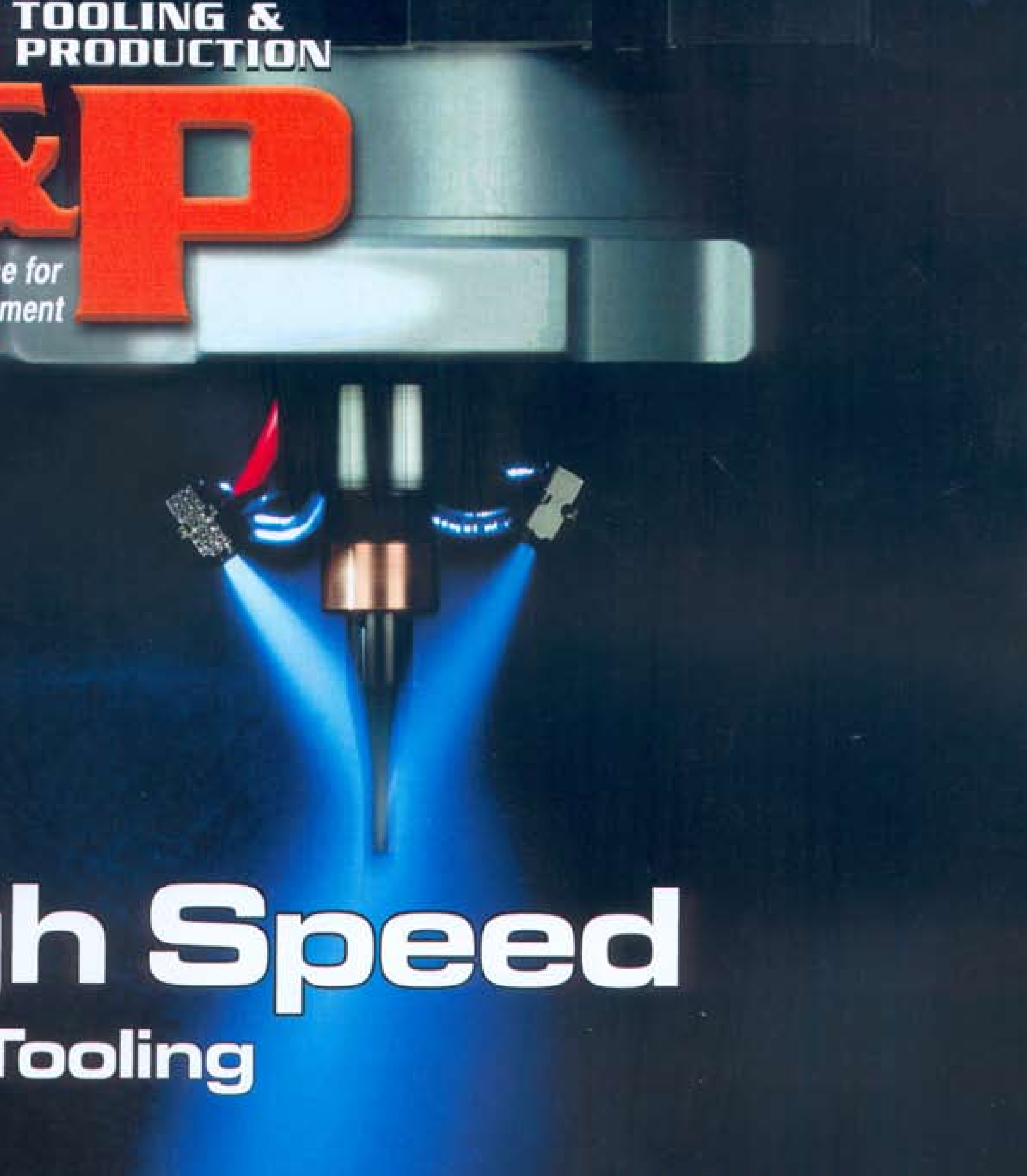

High Speed
Small Tooling

Cast a Vote for Manufacturing

IMTS Report

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High speed merges with small tooling

Look at micro-tooling operations as they push spindle speed limits

Ethanol quickly covers and cools more surface area than oil can on fast-moving micro-tooling.

What are the benefits of using high-speed machining with micro-tooling operations when dealing with non-ferrous metals and plastics? In this modified white paper provided by Datron Dynamics, the Milford, NH, company considers micro-tooling and high-speed machining, including the challenges of machining with micro-tooling, available technology, solutions, and several examples of feeds and speeds.

Workpiece sizes are decreasing, while part versions increase. The miniaturization in the manufacturing world demands changes in the manufacturing process. These increased demands require re-thinking in order to work more efficiently with smaller tool diameters. Smaller tool diameters require higher revolution per minute (rpm) speeds, which most conventional spindles cannot achieve. Even if they can, it puts undue stress on them by constantly red-lining the spindles. Conventional CNC equipment using tools smaller than 0.5" dia at 10,000rpm or less usually results in unfavorable feed rates and costly tool breakage.

A 1/4" high-speed cutter with 60,000rpm spindle flies through a 6061 aluminum sheet.

The traditional method of machining involves using comparatively large tools at fairly low speeds. Inherent to their de-sign, larger tools are often unsuitable for intricate machining. In order to attempt machining with micro-tooling, conventional machines must run very slowly and have a tendency to easily break the fragile tools. Large tools, by virtue of their mass, are resilient to the effect of chips. Smaller tools, on the other hand, are fragile and more susceptible to breakage.

Improper chip evacuation is a major cause of tool breakage. In fact, more small tools break because of inadequate chip removal than they do for incorrect machining parameters. Chips must be removed from the cutting channel in order to minimize breakage possibilities. Small tools require high spindle speeds, but they need to go even faster in order to kick the chips out.

Definitions of size and speed: Micro-tooling involves mills and drills with a diameter of 0.250" or less. It is required for intricate, very detailed machining, and works best with high-speed spindles. High-speed machining has no set definition or absolute parameters, but one workable definition is machining with spindle speeds of 25,000rpm or more.

Road to efficiency

The best approach to efficiently machine with small tooling is a three-fold process. The three interrelated elements are: 1) micro-tooling design; 2) low-viscosity coolant; and 3) high-speed machining technology.

Micro-tooling design: Scaling down the tool geometry of larger diameter tools to a smaller format yields unacceptable

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feed rates and unsatisfactory finishes. Tooling requirements change when tool diameter is decreased and spindle speed is increased. Conventional tooling using inserts is not appropriate for micro-tooling applications. This is primarily because of the required higher rpm rate

Vacumate — a vacuum table — secures parts with minimal surface area during machining and lightweight Quick-Pallets improve repeatability on jobs with frequent changeover.

The VelociRaptor provides feed rates up to 1,000ipm with close tolerances and optimized cycle times.

rather than the tool diameters involved. Increased rpm rates require a properly balanced tool with significantly increased chip room to ensure proper chip removal and to prevent chip burn-up. Efficient machining with small tools requires the tools to be optimized specifically for high-speed machining applications. The proper geometry of micro-tooling, together with high-speed spindles and proper coolant, can totally eliminate deburring as a secondary operation.

Coolant: High-speed machining with micro-tooling creates enough heat that steps can be required in order to cool things down. While high-speed machining technology has certain advantages that work toward reducing heat, that technology alone is sometimes insufficient to handle the entire task of cooling. An efficient coolant system is still required for certain applications.

The coolant eliminates heat and serves as a lubricant as well, thus enabling the tool to move swiftly across the surface. Try to cut a cold block of butter with a cold knife; it's difficult work because there's nothing aiding the blade as it tries to move across the butter's surface. However, if the knife is heated, it will effectively melt some of the butter, thus providing lubrication to the blade and enabling it to move easily across the butter, so efficient cutting can be accomplished. The same principle works with high-speed machining. The micro-tooling needs a lubricating agent with a lower viscosity than water. Lower viscosity is needed because the coolant needs to make it to the cutting edge of the tool at the high spindle speeds involved. Emulsion-based coolants have a higher viscosity than water, and thus are ineffective as a lubricant for high-speed machining with micro-tooling.

Available micro-volume coolant spray systems can use ethanol, a form of alcohol that occurs naturally in the sugar fermentation process. Ethanol is ideal for non-ferrous metals and some plastics. However, steel-based materials require an oil-based coolant. Thus the advantages of ethanol coolant are not available for ferrous machining. This is because carbide tooling on steel surfaces can cause sparks, which could create a rather highly dynamic situation if exposed to an alcohol-based coolant.

Conventional flood-coolant is petroleum-based. Such coolants need to be properly disposed of, with attendant costs. Ethanol doesn't need to be disposed of or recycled, because it simply evaporates. Although flammable, the low-evaporation point makes ethanol a very efficient cooling and lubricating agent for high-speed machining operations. Since it is a natural chemical, there is no negative environmental impact, no waste, no clean-up, and therefore no cost. In addition, ethanol as a coolant does not leave any residue on the machined parts, thus eliminating the costly secondary operation of degreasing the parts.

High-speed machining technology: The smaller the tooling, the higher the spindle speed an operator will need to efficiently machine the parts. High-frequency spindles with speed ranges from 6,000rpm to 60,000rpm are ideal for milling, drilling, thread milling, and engraving using micro-tooling.

High-speed machining technology uses high rpm rates, taking a smaller stepover, but with significantly increased feed rates. Move your hand through the flame of a burning candle. If you move too slowly, there's enough time for the flame to cause damage. But if you sweep your hand swiftly through the flame, there's insufficient time for the fire to damage your skin. The same principle applies to high-speed machining with micro-tooling. Move fast, and there's insufficient time for heat to feed back into the part and cause issues.

During the machining process, the tool continually carves a chip out of the workpiece. The generated heat develops approximately 40 percent from friction on each side of the tool, and 20 percent from the deformation (bending) of the chip. Therefore, about 60 percent of the

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heat is inside of the chip. High-speed machining tries to evacuate the bulk of the heat with the chip, providing for a cleaner cut. The better machining quality is based on cooler tooling, lower machining forces, and therefore less vibration.

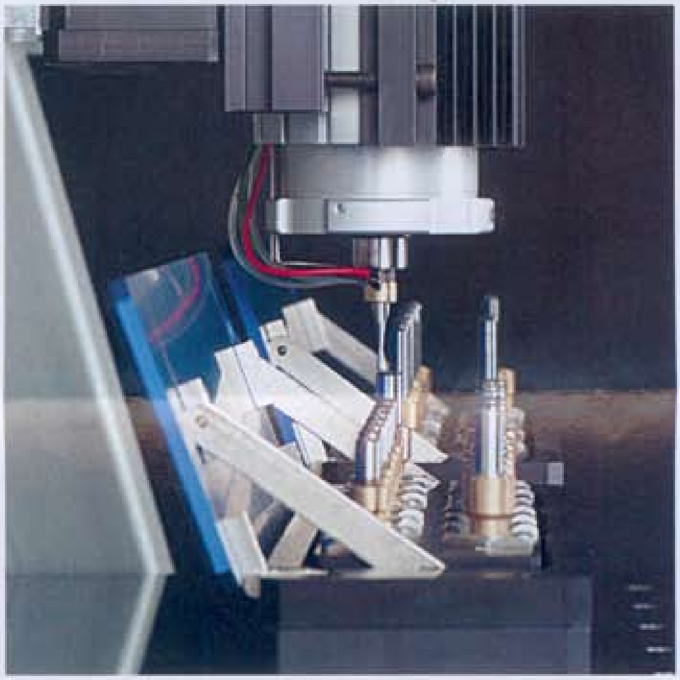
The high spindle speed reduces the chip load to less than 0.005". Such a low chip load significantly reduces the forces between the tool and the material. High-speed/low-force machining develops less heat, reduces tool deflection, and allows machining of thinner walled workpieces. This all results in better surface quality, cooler machining, easier workholding, and better accuracy.

Machine dynamics

The interrelated elements of the available technologies already noted are possible because of the dynamic nature of machines which perform high-speed machining with micro-tooling. The latter are relatively lightweight, which gives them a wide range of motion, agility, flexibility, and versatility, coupled with impressive speeds. Conventional machines are heavier and don't have the same degree of speed and maneuverability available to them, but they can machine with larger tooling. Conventional machines are like SUVs, which, though powerful, lack high maneuverability or the ability to stop on a dime. Sports cars, on the other hand, are powerful as well, but also possess a high degree of control and nimbleness because of their very design and construction, which describes exactly what machines capable of high-speed machining with micro-tooling are all about.

And just as you can't put a spoiler and racing stripes on an SUV and expect it to perform like a sports car, you can't retrofit a high-speed spindle onto a clunky conventional machine and expect it to efficiently accomplish high-speed machining with micro-tooling.

When designing a machine, you can go in one of two directions. You can build your machine big and powerful, able to drive big tools with a big spindle. Driving big tools requires high force, which means a big motor with heavy mass. On the other hand, you can build a lighter machine specifically for micro-tooling. A machine designed for high-speed machining with micro-tooling inherently encounters less machining force, and can be designed for speed and nimbleness without requiring a big motor to drive it.



Datron's tool checker is a mechanical sensor that measures tool length and can detect a broken tool. The software can be programmed with a macro to initiate a tool check at regular intervals.

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Which wing is more important for an airplane to achieve flight, the left or the right? The answer, of course, is that both are equally important and necessary for the plane to fly. Without both, the plane goes nowhere. By the same token, each part of the three-fold process is equally important in order to achieve efficient high-speed machining. Without all three, the high degrees of efficiency, reliability, and flexibility are lost.

However, if applied together the three-fold process can provide you with breathtaking manufacturing speeds, at an improved product quality. But it does not stop there. In addition, this process is capable of totally eliminating secondary operations like deburring and degreasing.

Cutting in practice

Here are two examples of high-speed machining, as done by Datron's machines. A 1/4" single flute cutter in 6061 aluminum, going 1/8" deep. The machining runs at 45,000rpm and is cooled by ethanol. Datron machines at 250ipm feeds.

Secondly, using a 1/8" double flute high-speed cutter (HSC+) with low-helical angle on a 1/8" 6061 machined through aluminum sheet, at 50,000rpm and cooled by ethanol. Datron machines at 200ipm feeds.

There are certain rules of thumb for high-speed machining. First of all, avoid red-lining your spindle, as this increases wear and tear on it and significantly reduces its lifetime. Machine with a maximum half the tooling diameter in Z. Machine with a smaller step-over but with higher feed rates. And finally, move fast and evacuate the heat with the chip.

Right tool, right job

It all comes down to the right tool for the right job. A golfer wouldn't use a driver on the green, nor tee off with a putter. Conventional machines retrofitted with high-speed spindles cannot hope to approach the high standards required for high-speed machining. Only a machine built from the start for the purpose of high-speed machining with micro-tooling can satisfy the exacting expectations.

High-speed machining with micro-tooling offers lower force, less tool breakage, no thermal growth, better surface finish, elimination of deburring and degreasing, and less tool vibration. Spindle speeds of up to 60,000rpm allow faster machining than ever with micro-tooling while providing better part quality. **Datron Dynamics, www.rsleads.com/610tp-159**