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The 10 commandments of dry high-speed machining

Ten tips can help shops get the most out of cutting and drilling with little or no coolant.

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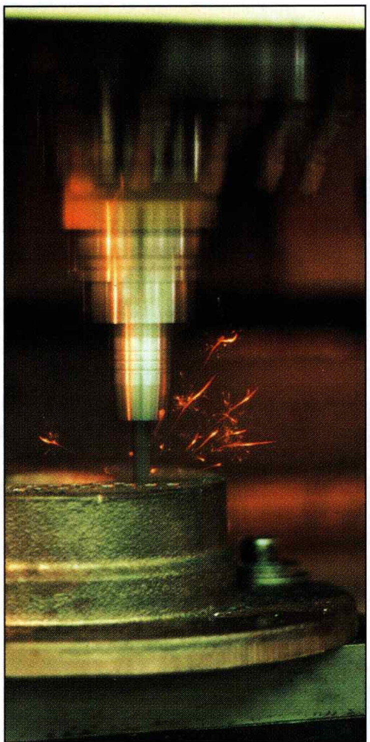
Dry machining is making inroads onto many shop floors, as it eliminates or greatly reduces coolant use, often cutting costs and providing a healthier working environment. Where many shops run into trouble, however, is in integrating dry machining into their existing operations. Fortunately, the following "10 commandments of dry high-speed machining" can serve as a guide to make the most efficient and economical use of dry machining technology.

The first commandment of dry machining concerns holemaking. Can a shop perform all operations dry, especially drilling? This is important, because it would be illogical to perform most cutting operations dry, or near-dry, then use coolant to drill holes.



Combining new coatings with microfine-grain carbide materials and HSK toolholding helps manufacturers in ultra-high-speed machining in dry and near-dry conditions. Here, a high-performance carbide drill from Guhring dry machines cast iron brake parts.

Of course, turning or milling operations are the easiest to convert to dry machining. In these operations, cutting edges are exposed and chips leave the cutting zone quickly, having little contact with the workpiece and tool. The chips, therefore, serve as a medium to dissipate heat. On the other hand, chips are not so easily flushed out in a drilling operation, allowing heat to build up quickly in the confined depths of the hole. This also applies to operations involving taps, fluteless taps, and reamers.

Companies often believe that making some operations dry will save a bundle in waste disposal costs. However, the greatest savings is in eliminating or simplifying coolant-management systems—whether they be central units supplying all machines on a shop floor or stand-alone units.

The second commandment recommends using high-performance carbide or diamond tools with honed cutting edges. Dry machining places considerable physical and thermal stress on tool cutting edges. Edge honing is vital in increasing cutting edge strength, as

Dry high-speed machining's 10 commandments

1. **Dry holemaking** for total success
2. **Honed cutting edges** to lower cutting temperatures
3. **Multilayer hard coating** for optimum thermal protection
4. **Integrated soft coating** to fight edge buildup and increase tool life
5. **External mist lubrication** for machining economy and flexibility
6. **Internal mist lubrication** to maximize productivity
7. **Custom tool geometries** for reducing cutting friction
8. **Suction systems** to evacuate mist, fumes, and chips
9. **New machine concepts** for fast, effective hot chip removal
10. **Faster, not slower cutting rates** to improve tool life and control heat

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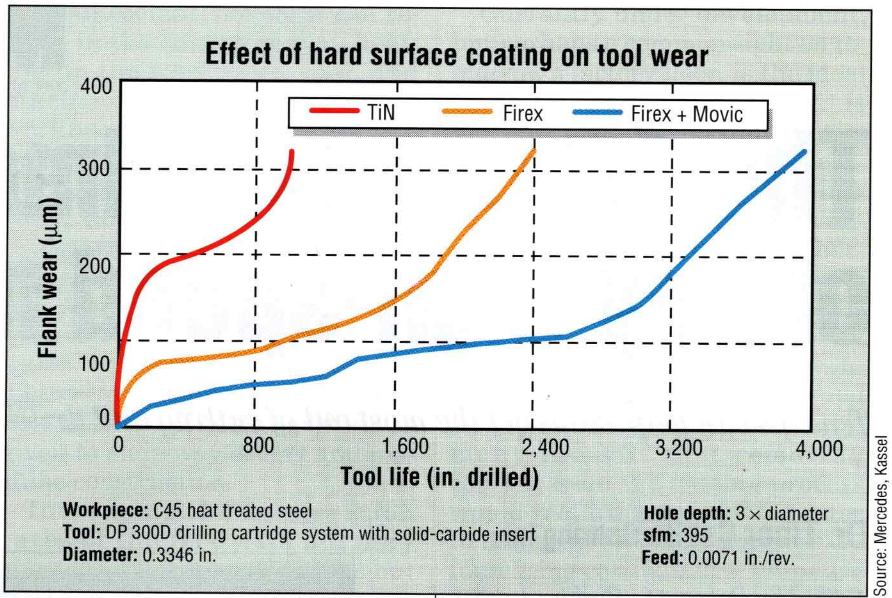
non-honed edges have a tendency to crack, gall, and crumble under the stress of dry machining. However, honing does reduce edge sharpness, which can increase heat generation during machining. The larger the hone, the duller the edge and greater the heat generated. By permitting both a sharper edge and a smaller hone, ultra-fine grain carbide and diamond substrates deliver the edge strength and reduced heat generation required for optimum tool life and performance.

The third commandment requires the use of a tool with a thermally protective hard surface coating. Even with the sharpest tools, high temperatures build up quickly and must be diverted away from the tool. Among conventional coatings, TiAlN (titanium aluminum nitride) has been the top choice for improved thermal insulation during dry machining. But the adhesion characteristics of conventionally applied, single-layer TiAlN coating have not supported optimum performance.



Under the dynamic stress of dry machining, single-layer TiAlN has a tendency to fissure, crack, and flake off the tool. Multilayer TiAlN coating, whose structure inhibits surface fractures from reaching the tool substrate, offers significantly improved performance. New coatings such as Guhring's FIREX™ multilayer hard coating, which is comprised of distinct, alternating ultra-thin layers of TiN (titanium nitride) and TiAlN coating, offer even better results. FIREX's structure combines the good adhesion characteristics of TiN, high heat resistance of TiAlN, and the ability to absorb cracking of TiCN (titanium carbonitride).

Guhring's new FIREX product is a multilayer coating that combines TiN and TiAlN. The company reports that, in 8620 steel, a single FIREX tool produced 12,000 holes, while a TiN equivalent made just 2,500.

One other important note: tools must be recoated after regrinding to ensure they can handle the high heat of dry cutting. If a tool is not recoated, the heat is transferred into the tool without impediment, resulting in premature failure. Even the residual coating in the flutes and on the tool body cannot overcome this problem.

The fourth mandate of dry machining is the need for a soft, nonstick coating. Tools must have a lubrication coat (possibly on top of a hard coat) to reduce the problem of built-up edge. In addition, recoating is needed after every regrind. Guhring produces such a surface treating, called Movic. This soft, glide coating essentially integrates lubricant into a tool and creates a good sliding surface that minimizes friction between chips and tool flutes. Implanted into the tool surface, Movic remains within the surface pores during the life of the tool, although its lubricating effect is strongly reduced after regrinding.

The fifth commandment recommends using external mist lubrication for cost-effective, near-dry high-speed machining. Compatible with most existing machinery, this approach uses a spray-jet coolant delivery system, which suspends a nanometric amount of coolant in a fine air-coolant mist that continuously coats the moving tool. In spray-jet, or "beam sparkling," coolant systems, coolant and air are directed under pressure independently through a multiple-nozzle spray head, with coolant traveling through an inner nozzle and a faster airstream through an outer nozzle. On exit, the airstream "pulls" the coolant out of the inner nozzle. The speed of the airstream then contains the coolant-air mixture, preventing it from expanding or collapsing.

With mist lubrication, coolant volume drops to less than 50 ml/hour, compared to typical flood-coolant volume exceeding 6 liter/min. Near-dry machining with external mist lubrication is recommended when working in steel, drilling holes deeper than five times the hole diameter, and other applications where totally dry machining is not yet commercially viable.

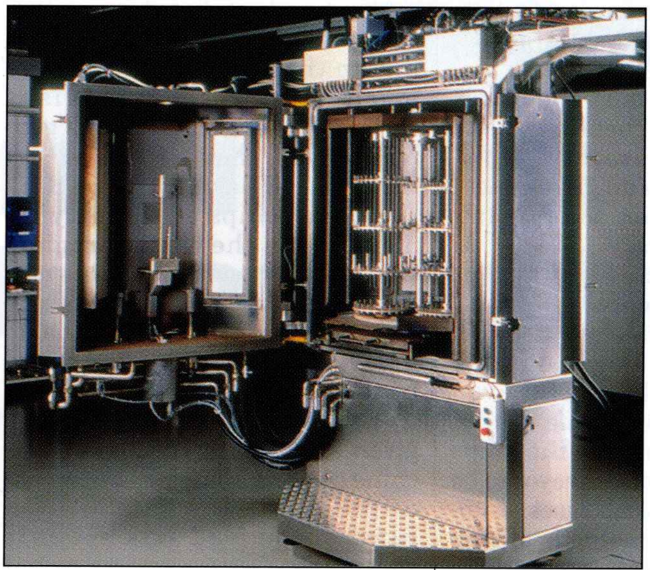
New coating beats the heat

Properly applied, coatings increase tool hardness, toughness, and heat resistance, permitting long tool runs at aggressive speeds and feeds. In addition, coatings can reduce machining friction and heat buildup, resulting in less machine wear, tool cratering, and flute packing. Another bonus is that coatings have no chemical affinity to workpiece materials, so they resist edge buildup and galling.

Guhring recently introduced its multilayer FIREX™ hard coating, developed in cooperation with Platit of Switzerland. This coating combines layers of titanium nitride and titanium aluminum nitride, and features a hardness of over 90 Rc. Its maximum operating temperature is 1,470° F.

The red-violet coating is deposited using physical-vapor deposition. Guhring uses a unique cathodic arc process to apply FIREX, which produces a smooth outer coating layer.

According to the company, coating quality can be severely compromised if tools are not properly prepared before going into the coating chamber. Therefore, Guhring cleans each tool in a fully automated five-stage ultrasonic cleaning system. It then sorts each job by tool size, geometry, and material type to achieve optimum coating uniformity and thickness. Once the tools are cleaned and sorted, they are placed in the coating chamber and closely monitored to ensure that neither the structural integrity nor geometry of the tools is altered.



Guhring deposits its multilayer Firex coating on cutting tools using a system manufactured by Platit of Switzerland.

The sixth commandment suggests the use of internal, or coolant-through, mist lubrication—wherever possible. Delivering the coolant-air mist internally through the spindle and tool and directly to the cutting edge is particularly effective and reliable, especially in extremely deep holes, because successful application is not governed by the accuracy of the airstream or by tool length. The only question is whether the "containing" air can transport the coolant effectively around corners and through void areas, narrow passages, and openings that may be found in the spindle, toolholder, or ancillary pipework. Additionally, the rotation of the spindle subjects the airstream to centrifugal force, causing the mixture to hurl against the bore surface.

Fortunately, there are two commercially available solutions to these problems. The first addresses the problem of the coolant-air mixing in the spindle close to the tool. A "sponge" of heavy metal within the spindle stores the coolant. When the airstream passes through, the spindle pulls coolant particles out of the sponge and directs them onto the cutting edge. The second option mixes both the coolant and air before it enters the rotating spindle. Low-pressure air only transports a small amount of coolant through the spindle. This coolant can be broken down into particles smaller than 1 μm by the means of "chopping" devices or by boosters.

A key limitation to internal mist lubrication is the availability of coolant-through tooling for smaller diameter machining. Tools with diameters less than 3 mm are rarely available with coolant ducts. As such, shops should be prepared to use both external and internal lubrication methods as needed.

The seventh commandment concerns choosing tool geometries suitable for machining dry. Current standard tool geometries are not economical for dry machining, so shops should select optimized tool geometries to reduce friction between the tool and the chip.

Optimized tooling has two distinguishing characteristics. First, it reduces the amount of tool surface that comes into direct contact with the workpiece. For example, a drill requires reducing back taper, land, and flute helix angle. Secondly, optimized tooling places maximum lubrication on the tool surface where built-up edges are likely to develop. This is done by opening the lubrication duct into the flutes or between the lands.

The eighth commandment recommends the use of suction to achieve the three-fold goals of removing lubrication mist, fumes, and chips from the cutting region. Extended exposure to airborne lubrication mist and fumes presents potential health risks to machine operators, while unevacuated chips can reduce tool life and threaten machining quality and accuracy.

When dry machining on conventional machine tools, chips often remain on the workpiece, in the fixture, and on various key areas of the machine. But even with "dry machines," one cannot be totally sure that all the chips will quickly fall on a conveyor to be hauled away. In such cases, automatic or manual methods of chip evacuation prove highly effective.

The ninth commandment advocates adopting new machine concepts for fast, effective hot chip removal. When using flood coolants, fast chip removal is rarely considered. However, without coolant, hot chips can remain in the cutting region, heating up the workpiece, tool, and machine. Overheating risks workhardening and serious geometric and dimensional flaws in the finished part. It is essential, then, that chips are quickly removed from the cutting region. One remedy would be to use gravity. Chips can fall on a conveyor if tools are used vertically or diagonally upward. The diagonal method is probably the more effective method if consideration is given to slide-way covers and machine construction.

Increasing the acceleration rates of the feed axis not only shortens machine cycle times but also reduces the risk of "underfeeding" through slow acceleration (as with conventional machines). The direct result of this latter feature is increased tool life.

Currently under development, but perhaps a common sight on tomorrow's factory floor, is the ideal machine for dry machining. It will incorporate "regulating circuitry," which will take temperature measurements at key points and, in cases of excessive heat, automatically compensate for thermal effects by axis movement.

The final commandment asks shops to run their machines at cutting rates faster than conventional machining to improve tool life and control heat. Initially, many thought that removing coolant from the cutting process would require lower cutting rates to maintain tool life. However, by increasing cutting rates, chips are forced to leave the hole quicker, reducing heat and lengthening tool life. ●