Technical Report—

Improving Tool Life with Minimum Quantity Lubrication

Report coutesy UNIST

If you knew of a way that you could significantly improve tool life, decrease the wear and tear on your machine, clean up your plant, and "go green" all at the same time, would you do it? Do you think your competition might? Doug Watts, Chief Technical Officer of MAG Americas, asked this question. Actually, in a recent piece for AMT News, he states it more bluntly: he asks if, in the long term, American manufacturers can really afford to not move to Minimum Quantity Lubrication (MQL), a technology that is environmentally responsible and reduces manufacturing costs. There is no such thing as a free lunch, but a committed well planned move toward MQL can help your operation clean up – both literally and financially.

What is MQL?

Minimum Quantity Lubrication—the process of applying a minute amount of a quality lubricant directly into the cutting tool-work piece interface—is effective in a wide variety of metal cutting processes, including sawing, turning, milling, drilling, and tapping. Manufacturers using MQL have seen tremendous advantages. According to one study, Ford saw a 13% decrease in overall costs after the implementation of MQL. This decrease in costs was due to better cutting tool life, a significant fluid reduction, reduced costs of coolant handling, decreased maintenance, and an increase in machine uptime. This article will highlight three critical elements necessary for successful implementation of MQL and then focus specifically on the positive effects MQL can have on tool life and performance.

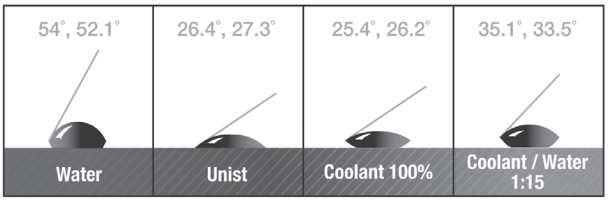
The First Critical Element: Lubricant

Choosing the right MQL lubricant is important. A recent paper demonstrated how poorly water-based fluids fared in covering a metal surface when compared to an oil-based lubricant.

Furthermore, not all oils are created equally. Organic oils, such as Unist's Coolube®, which was used in above study, are better than mineral based oils because of the polar molecules found in them. Polar molecules have opposite electrical charges at each end which creates a thin, consistent bond between Coolube® and the metallic surface. This gives an even, strong, and durable layer of lubrication. (See polar properties image.)

Finally, a high quality MQL lubricant is not only stable against oxidative and thermal breakdown, but is also completely biodegradable.

Surface adhesion comparison



The Second Critical Element: Application

The second key for successful implementation of MQL is precise application of the fluid. To effectively do its job, the lubricant needs to get between the cutting edge and the work piece. With too little lubricant, friction is not reduced and heat builds up in the tool whereas using too much lubricant is wasteful and can lead to premature tool wear. The goal of MQL is to maintain a thin film of oil that lubricates the cutting interface.

Some cutting applications will require multiple nozzles or unique configurations to ensure lubricant is uniformly applied during the cut.

In many cases, specifically drilling, the tool is buried in the material and it's difficult to maintain a consistent film of lubricant with an external spray nozzle. A good solution for this problem is to use oil-hole drills, especially for deep holes. A well-designed through-the-spindle applicator ensures proper application of the fluid even when the tool is buried in the material.

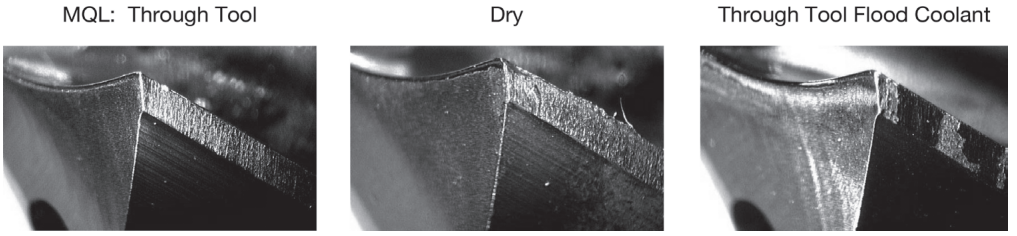
The application system must be able to deliver fluid in a precise and repeatable manner. Positive displacement pump systems are significantly more consistent than a venturi type applicator. Additionally, how the oil and air get mixed will affect the consistency of fluid delivery. The best system is one where the oil and air are maintained separately, and mixed just before they are applied.

Air flow rate can play an important role in overall system satisfaction. Too much air flow may cause misting, which can fog up the air. The goal is to use just enough air to get the oil to the tool.

The Third Critical Element: The Machining System

Transitioning to MQL involves more than simply changing from a water-based coolant to an oil. It requires looking at the entire machining operation as a whole: the MQL applicator, proper tooling, and adequate chip evacuation. Each of these factors needs to be evaluated in order to achieve optimal results.

The proper application system depends on the operation, variations in the material size and shape, and the design of



Comparison of cutting tool edges

the machine. In many cases, a manually adjusted MQL applicator with a consistent output will work well. For more sophisticated CNC operations, a completely programmable MQL unit interfaced with the machine is ideal. One such system, the Unist Revolution™ system interfaces with the machine controls and allows the fluid output to be programmed dynamically. This allows various size tools to be used in the same job and different jobs may be run without having to make manual adjustments to the applicator.

Chip evacuation is another important factor when considering a move to MQL. Without coolant to wash the chips away, machining efficiency could be negatively affected.

Orienting the work so the chips are moved out by gravity may help solve this problem. In some CNC machines, the chips naturally fall down vertically and can be removed from the system.

In other situations, an air blow-off nozzle can be used to remove the chips. A programmable and intermittent air blast can effectively aid in chip removal, and help to eliminate the possibility of re-cutting a chip.

Other strategies for chip removal include using MQL specific tooling and vacuum systems to remove the chips. Ultimately, the solution in any particular situation will be as unique as the job itself.

Improved Cutting Performance/Tool life

Many studies have been proven the effectiveness of MQL in improving tool performance and life. In a study done on AISI 4140 Steel on a Mazak AJ125/40, the MQL system showed the least amount of tool wear when compared to machining with coolant or machining dry. The end result: tool wear over 1600 holes was cut in half using MQL. (See cutting tool edge comparison image above.)

Tests run by another manufacturer on a horizontal machining center found that the number of holes on a carbide drill increased from 2743 to 10550 – a 380% increase!

One MQL user found tool life increased 41% on a CNC lathe, another company found an eightfold increase on parts per tap, and yet another saw production rates increase 400% on a mill.

A study in The International Journal of Machine Tools & Manufacture found that on hardened steel with a carbide end mill, flood cooling resulted in the shortest tool life due to severe thermal cracks while the use of MQL led to the best performance.

Surface & Coatings Technology found that in high-speed end-milling of cold-worked die steel, the tool wear of MQL vs. flood coolant was almost half.

On Titanium, according to Machining Science and Technology, MQL remarkably and reliably improved tool life, and reduced cutting force due to the better lubrication and cooling effect.

What about difficult metals like Inconel? The people at the UK Center for Manufacturing found that MQL reduced the axial and radial forces, surface roughness improved even at large feeds and depths of cut, and chip breaking improved significantly.

Conclusion

Does MQL work everywhere? Of course not, but it works well on many materials, including most non-ferrous materials, steels, titanium, and specialty alloys. It is widely used in Europe, and has been proven both in the labs and in the field. With the right lubricant, the right application and right machining system you can see remarkable increases in tool life while saving money, cleaning up your plant, and being environmentally responsible. ■