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Fine Ideas

Ultrafiltration of coolant lengthens tool and machine life.

A coolant does more than lubricate the cutting tool/workpiece interface and limit the amount of heat generated during machining. It also performs the essential job of flushing chips from the cutting zone. Chips must be flushed continuously to prevent them from being recut and to minimize tool breakage and the marring of finished surfaces.

People who cut metal understand the importance of chip removal and have a program in place to handle big chips. What few know, though, is that microscopic chips cause greater damage than large chips.

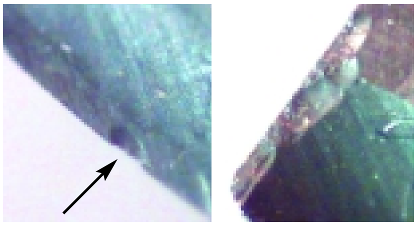
These particles—called fines—lodge between the tool and workpiece and effectively act as a grinding media. They abrade the cutting tool and workpiece, leading to predictable results: excessive tool wear and poor-quality parts. Efforts to counter accelerated tool wear and poor finish often leads machinists to lower cutting speeds—an action that trims profits.

The coolant sump in an average machine shop contains about a cup of fines. If the cutting fluid is not filtered, the fines are recirculated along with the dirty fluid and returned to the work zone. As the coolant flows between the workpiece and tool, the particles are ground and reground. The finer they become, the easier it is for them to enter critical spaces and degrade machine tolerances.

Chip removal is not filtration, and regular filtration is not good enough for the tolerances required today. It is certainly not good enough for high-speed machining. A higher level of filtration—ultrafiltration—is needed. An ultrafiltration system is able to capture 99 percent of all particles down to 1 micron.

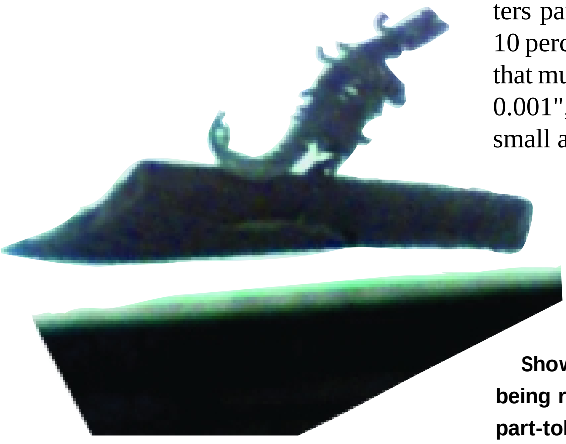
A leading aircraft manufacturer filters particles whose dimensions equal 10 percent of the tightest part tolerance that must be met. So, if that tolerance is 0.001", the company filters particles as small as 0.0001".

Besides removing fines, ultrafiltering removes the bacteria and fungi that typically grow in bottom sludge and feed on



Edge chipping of a two-flute drill run in dirty coolant (60x). The photo at left shows a chip in the side of the drill. The other photo depicts three distinct fracture planes where the carbide tool was sheared away because a particle lodged between the drill and the workpiece. In this case, the failure mechanism was chipping rather than conventional wear.

Corners of an endmill run in coolant containing a high level of microscopic particles (60x). The corners have been chipped to the point where they can no longer properly engage the workpiece. When one edge chips, it's likely that the trailing edge will chip, because it slams into the workpiece with more force.



Shown is a 60× photograph of a 0.075"× 0.122" particle found in coolant that was being recirculated to the cutting zone. The fine is 150 times larger than the 0.0005" part-tolerance requirement. One aircraft manufacturer filters out all fines from its coolant that are larger than 10 percent of the tightest tolerance of the part being machined.

All images supplied by Northwest Research Institute

Friction: source of metalcutting problems

Cutting metal generates friction that causes the temperature of the workpiece and tool to rise. Excessive heat can result in a number of undesirable consequences, including improper part size and shape, a poor finish and unsatisfactory tool life.

To prevent these problems, the cutting fluid must cool and lubricate the tool/workpiece interface, as well as flush chips from the cutting zone.

With respect to the workpiece, two types of friction develop: external and internal. The former, caused by contact between the tool and part, generates approximately one-third of the heat. Internal friction, which is the workpiece material's resistance to flow as it deforms in the shear zone, generates the remainder. Efficient lubrication of the cutting zone reduces external friction and, to a lesser extent, internal friction. The result is improved metalcutting.

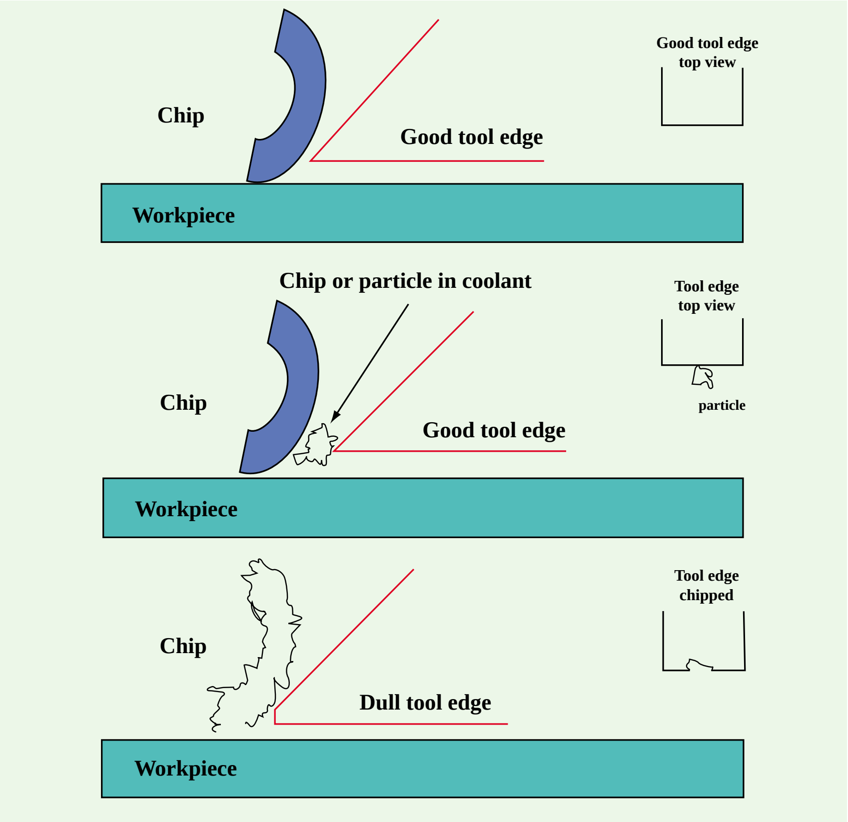
The cooling effect provided by a coolant keeps parts thermally stable, which aids in controlling their size. And given the number of parts being finished today without secondary operations, such as engine blocks and transmission cases, a cutting fluid's capacity to keep parts dimensionally stable during machining is critical.

Additionally, a coolant extends tool life by preventing it from exceeding its critical temperature while in the cut. Above the critical temperature, coatings fail and tools soften, wear too rapidly, and fail to deliver specified surface finishes and part tolerances.

As coolant becomes dirty, it degrades and stops providing many essential benefits, such as lubricity and the ability to control heat, bacteria, staining and rust. Therefore, filtering should be part of a total coolant-management program.

The goal should be to maintain a coolant at the contamination level reached after 1 week of use, and keep it at that level for a year or more. Restoring coolant to an as-new condition through filtration and treatment is possible but seldom cost-effective.

—T. Walz



This series of illustrations depict how microscopic particles in coolant can cause the cutting edge to chip and dull.

tramp oils and greases. Purging these contaminants helps eliminate unpleasant shop odors. Filtering also oxygenates coolant, which curbs bacterial growth.

Company Sees Benefits

Properly filtered coolants improve profits by allowing increased operating speeds, elevating quality, reducing coolant usage, and extending machine and tool life.

One company that has witnessed the benefits of ultrafiltration first-hand is Metal Form, a division of Tru-Circle Aerospace Corp.

Metal Form, Kent, Wash., focuses intently on quality at every level. It works to "tenths" and constantly strives to maximize tool life. Each of the company's machine carousels is equipped with between 65 and 100 dedicated tools and, next to each machine, is a rack containing up to 200 additional tools. Coolant is predominantly delivered through the spindle at 200 to 1,000 psi and at a rate of 35 gpm.

Metal Form is willing to purchase the equipment required to meet its customers' needs, but it's also careful about what it buys. For example, a while ago it spent $1.6 million for a new machining center but passed on a $15,000 tramp-oil separator for coolant. In-house research showed that equivalent results could be attained by decanting coolants in a holding tank.

Metal Form has also studied cutting tool wear patterns. Specifically, company engineers wanted to know why their tools were dulling prematurely. Their analysis showed that much more dulling results from tool chipping than from conventional wear and that a large percentage of this chipping was caused by hard particles in the cut.

Metal Form was removing large chips from the cutting zone and, as is common throughout industry, thought that doing this was enough to keep its coolant clean. However, laboratory analysis showed that its coolant contained about six times more suspended solids than the recommended standard of 200 ppm.

Ultimately, the company found that with basic filtering it was able to reduce the particle count from 1,200 ppm to 150 ppm.

Metal Form chose to test a freestanding filtering system, not an in-line system. This was done to prevent machining performance from being affected. The engineers feared that an inline system would slow coolant flow or cut it off completely.

The cost of the filtering system was about $2,000. The return on investment, in terms of increased tool life, was estimated to take 4 to 6 months. ROI with respect to reduced coolant usage was put at 10 to 12 months. The major savings, though, was expected to come from reduced downtime and machine maintenance.

Totaling up all the anticipated savings—tool and coolant life, reduced energy consumption and decreased labor costs—Metal Form estimated that the payback period would be 2 months.

An ultrafiltering unit with a 3-year supply of filters costs about $3,000 to $4,000. A company wanting to estimate the ROI for the unit would need to gather accurate cost data on tool life, coolant usage, labor and machine downtime.

Available Systems

Two basic styles of filtering systems are available: freestanding and in-line. Freestanding units are available that filter either the sump inlet or outlet, or connect directly to the machine coolant lines.

Both styles work well. However, coolant flow and pressure change as the filter becomes loaded. This can cause problems for an in-line system not designed to handle the extra load. Moreover, with an in-line unit, there's the added expense of connecting it the machine, and when this type of unit is down so is the machine.

Theoretically, a filtering unit that is plumbed directly into a machine's coolant line will deliver cleaner coolant to the nozzle than a freestanding unit. Yet, in practice, standalone units remove 99.6 percent of particulate material 1 micron or larger. For most operations, that is a sufficient level of filtration.

About the Author

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