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A "cool-to-the-touch" dry machining philosophy can lower costs and boost productivity.

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PROFESSIONAL PRODUCT & MANUFACTURING SOLUTIONS

The expanding use of dry machining is prompting toolmakers and machinists to rethink processes and strategies, with the goal of reducing operating costs and improving productivity. Hence, the principle of "cool-to-the-touch" machining could soon be a hot topic. By setting the parameters of an operation so that heat generated at the point of cut enters the chips and is carried away from the tool, a machinist can better control the results of an operation.

Machine operators have always known that there is a great deal of heat generated during machining processes. However, this fact is often overlooked or forgotten when the application traditionally involves using coolant. Under these conditions, when coolant is being used, it is usually difficult to optimize speeds and feeds based on the evaluation of temperature rise, because most of the heat generated during processing is carried away by the coolant. That makes it impossible to tell whether the part, the tool or the chips would have absorbed the heat during machining.

Some machining operations—such as tapping/threading, narrow cutoff, boring, grooving and deep drilling—obviously cannot be performed adequately without coolant, as the fluid doubly serves as a cooling agent and removes metal shavings from the cutting area. So, cool-to-the-touch machining principles normally cannot be applied successfully to these operations.

However, for most turning and milling operations, dry machining allows adjustments to be made to the machine speed and feed rate that can significantly improve productivity. When proper surface speeds are used, feed rates and depths of cut should be large enough that the chips carry away approximately 80 percent of the generated heat. The tool and the workpiece retain the remaining 20 percent of the heat.

When it comes to optimizing a dry machining process, purple reigns. The chips shown, with their deep purple hue, exemplify a dry machining operation in which a substantial amount of the heat generated by the procedure was transferred away from the tool. The part is an idler shaft for a diesel engine.

A Wave of the Hand

Conventional machine tool operating principles, on-the-job training and experience have taught machine operators to apply large quantities of coolant to the workpiece surface during lathe and milling-machine operations. However, using coolant in this manner generally results in: shortened tool life often caused by thermal shock; increased downtime due to frequent tool changes; frequent disposal of spent coolant; undesirable working conditions (messy workstations, slippery parts, etc.); accelerated appearance of rust when using improperly mixed or contaminated coolant; and increased operating costs.

On the other hand, applying the principles of dry machining and cool-to-the-touch process control can yield the following benefits: improved tool life; finished products that are easier to handle; shorter cycle times; elimination of coolant disposal; reduced operating costs; and elimination of finished product rusting in a JIT (just-in-time) system.

Each of the three processing variables—sfm, ipr and DOC—must be reviewed and controlled carefully to machine a workpiece successfully using a cool-to-the-touch strategy. Referring to operating manuals, training books and setup charts is a good start when setting up a new machining operation. These reference sources provide "rule of thumb" operating principles that are generally conservative.

Once a production run is set up based on "standard operating procedures," the parameters will need to be varied to determine the optimum operating condition. There is no nominal set of parameters that will allow this to be achieved for all applications. However, a dry machining operation can be optimized while tool life is maximized.

If your current approach to producing a part involves the application of coolant, the simplest way to start utilizing the cool-to-the-touch method is to turn off the coolant. After completing a pass or series of passes, stop the machine and hold your hand a couple of inches away from the workpiece—without touching it. You will be able to feel excess heat coming off the piece and know that it is hot—perhaps very hot—to the touch. If the heat radiating from the workpiece is not felt on the hand, it's safe to touch the workpiece—perhaps at first with a wetted finger—and gauge how hot it is.

Another way to determine heat buildup is to examine the chips' color. If the chips are straw-colored, they have retained a minimal amount of heat, and, thus, the workpiece is excessively hot. If the chips are a deep purple, they are sure to be very hot, while the workpiece won't be. It is this latter instance that is optimal. The heat is exactly where it should be—in the chips.

A turning operation performed on a piece of 8620 hot-rolled steel illustrates how well the procedure works. The 3½"-dia. workpiece needed to be taken down to 3¼". The material had been stored outdoors in frigid weather and was exposed to a warmer indoor temperature for only a few hours before turning. When loaded onto the machine, the surface of the material had started to warm, but the core of the material was still near the outside temperature.

After removing the ¼" of material using proper feeds and speeds, the core remained cooler than the original surface. Clearly, when conditions are right, the results are amazing.

A cold-formed 8640 steel ball stud for a truck steering linkage was machined at 1,800 rpm in less than 1 second using an uncoated carbide tool and cool-to-the-touch dry machining technique. Most of the heat of the operation was carried away by the chips, as evidenced by their deep purple color. Total machining time was 4 seconds. Tool life was 48 hours.

Best of a Touchy Situation

It is not possible to get 100 percent of the generated heat at the tool/workpiece interface into the chips, but there are some steps one can take to help get 80 percent or more of that heat into the chips.

First, start with a speed that is at least equal to the cutting tool manufacturer's recommendation. In addition, the DOC should be at least twice the nose radius of the cutting tool. Unless the workpiece and the machine are extremely large, a nose radius of $\frac{1}{32}$" works well under most conditions. Keeping the DOC greater than the radius of the nose produces a chip that's large enough to carry the heat away, keeps the cutting forces nearly parallel to the centerlines of both the workpiece and the spindle, removes as much material as possible during each pass, and allows effective chip control.

In addition, the feed rate when turning should not exceed one-half the nose radius. For example, with a $\frac{1}{32}$" radius, the feed rate should not exceed 0.0156 ipr with a neutral-lead tool. (Higher feeds can be used if a positive-lead tool is employed because of the chip thinning effect.) Exceeding the rule of thumb does not generally cause a problem, but care should be taken, as the potential for tool breakage increases. Experience is the key to attempting more aggressive feed rates.

Once the DOC and feed rate have been increased to where the workpiece shows signs of cooling, other changes are needed to reduce the machining temperature further. One set of changes involves increasing the DOC and reducing the number of passes. Some additional experimenting with speed, feed and DOC would be required to optimize the operation. There are no detailed calculations or instruction manuals that can provide these parameters; only repeated trial and error can establish the correct combination.

The operation must leave sufficient material for the final or finish pass, if required. The final pass should be consistent and not too shallow. This will reduce heat buildup and improve chip control, resulting in a finer finish. Passes that are too shallow, on the other hand, generate large amounts of heat in the workpiece and the tool, while generating chips that are very difficult—if not impossible—to break.

A final word of caution: During initial trials, the most significant risks involve tool breakage and downtime. Occasionally, the operating parameters may become drastically out of sync, and a tool may break. If this happens, the result will be inconvenience, a tem-

A cold-formed 1035 steel stretch bolt was machined in less than 1 second, with a total cycle time of 3 seconds, using two coated carbide tools under dry machining conditions. The part and the tooling were cool to the touch after the operation.

porary interruption of production and some possible workpiece damage.

However, the anticipated benefits from increased productivity and reduced coolant usage should more than offset these costs and the time required to determine the proper combination of operating parameters. During this initial period, the tool failure rate will probably be no greater than that experienced under conventional operating conditions.

Once these machining conditions are established for a particular operation, the increased productivity and overall savings go directly into increasing the job's profitability and the company's bottom line. Not only is reducing coolant use to zero a win-win situation for the environment, but coolant-free chips are much easier (and more lucrative) to recycle as clean scrap. Considering cool-to-the-touch dry machining for many routine turning and milling operations can be the competitive edge that is needed these days to keep a shop operating successfully.

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