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focus: moldmaking

▶BY ALAN RICHTER, MANAGING EDITOR

CUT TO THE FINISH

"Brutal" best describes the situation for moldmakers competing in the global economy. The need to meet shorter delivery schedules and reduce costs while maintaining quality continues to pressure—and sometimes sink—even the most efficient operations.

One area being targeted to save time and money is mold polishing. Presented here is a series of short articles on the subject of minimizing or eliminating manual mold polishing.

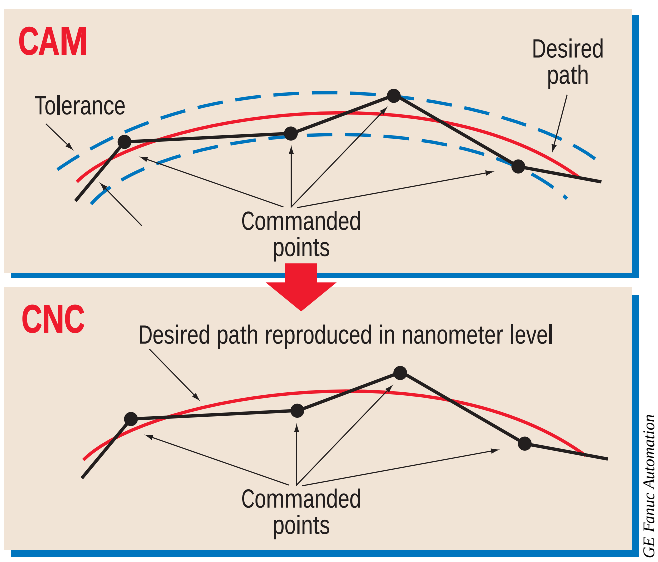
NURBS through nano-smoothing

Nonuniform rational B-spline interpolation can eliminate manual polishing of molds. But a moldmaker without a CAM processor that is able to provide NURBS output for the CNC would have to upgrade its CAM processor or purchase a NURBS-capable one to eliminate the post-machining bench work.

With GE Fanuc Automation Americas Inc.'s nano-CNC system and its nano-smoothing interpolation function, that is no longer the case.

Nano-smoothing "allows you to get the same accuracies and speeds as a NURBS program without having to go out and buy a new CAM processor," said Bill Griffith, CNC product manager for the Charlottesville, Va., company. "You can use your current CAM processor that outputs only linear segments."

Griffith explained that every CNC has a CNC processor and a servo processor. The CNC processor tells the servo processor the interpolation rate at which it needs to move. For example, a CNC with a 1-millisecond interpolation rate instructs the servo processor every millisecond how far the servo



The Fanuc nano-CNC system estimates the desired path using the minute line-segment program made by a CAM system, and then reproduces the desired path with a nanometer level of precision.

needs to move in the next millisecond. "With nanometer interpolation, the command unit is now 1,000 times finer," he said. "It gives much better control of the servomotors."

With a micrometer interpolation command unit, rounding errors occur. Consequently, all points specified in the program are not on an ideal curve, which can result in machined surfaces that are streaked. In addition, because the machining program is specified with linear interpolation, a curve becomes a polygon.

Griffith said: "Let's say every 1 millisecond the CNC processor tells the servo processor to move 12 counts. But, due to rounding, every fifth cycle of the interpolation rate it says to move 13 counts. With a nanometer interpolation command unit, the unit is so small—it's down to 1 millionth of a millimeter—we don't have that rounding. We may be doing 12.333 counts every interpolation rate."

By interpolating the generated NURBS curves in nanometers, the nano-smoothing function provides a machined surface that virtually mirrors the designed part's geometries. "The CNC does the NURBS-curve fit of the linear segments and does all the NURBS interpolation internal to the CNC," Griffith said.

He added that GE Fanuc's Series 16 and 18 products take the 3-axis linear part program and perform the NURBS-curve fit in the CNC, while the company's 30*i* takes a 5-axis program in linear segments and does the NURBS-curve fit. The latter allows a moldmaker to smoothly produce molds that require 5-axis machining at a significantly lower cost.

"A CAM processor that outputs 5-axis NURBS interpolation is very expensive," Griffith said. "We can take a 5-axis, standard CAM-process output of a program with small linear segments and run 5-axis nano-smoothing interpolation and get the same accuracies as a 5-axis NURBS program."

Retrofitting for efficiency

Retrofitting a high-speed vertical machining center with a CNC is one way to minimize manual mold polishing. King Machine of Akron (Ohio) Inc. realized this after it retrofitted a Johnsford VMC with a Siemens Sinumerik 840Di CNC package, said Rob Snodgrass, programming manager for King Model Co., the sister company responsible for the engineering work that is conducted. The package includes drives, motors and an ADI4 (analog drive interface for 4 axes) board to interface with the external spindle system.

"We use the CNC for axis motion control, as well as the spindle and auxiliary functions such as the toolchanger, lube system and the two rotary tables," Snodgrass explained.

The VMC performs milling and 4- and 5-axis simultaneous engraving on sidewall sections of tire molds. Typical molds have 25" to 60" ODs and are produced from 1020 steel or 6061 aluminum.

The VMC's ability to blend, or fillet, radii with form tools instead of having a benchman apply a disc grinder to form the radii and use a radius gage to make sure they are the correct size is a major benefit of the retrofit. "A lot of the time we'll come into a situation where we'll have a theoretical point on a surface that requires anywhere from a 0.030" to a 0.080" shoulder radius," Snodgrass said. "Prior to the retrofit, that was achieved by hand and it was very time consuming."

The retrofit package, along with special form tools ground to match the profile being engraved, allows King Machine to cut the needed radii directly into the mold. "Now, the benchmen polish off the tool marks rather than trying to actually form the part geometry," Snodgrass said. He estimated that eliminated 3 to 6 hours of bench work per part.

King Machine saved significant money by retrofitting. "The alternative was purchasing a machine that costs significantly more to do the same job," Snodgrass said. "We saved about 50 to 55 percent vs. buying new equipment."

The retrofitted VMC further boosts productivity by taking larger cuts at a higher rate when finishing. Snodgrass said: "Prior to retrofitting, the equipment was capable of taking a 0.010" to maybe a 0.020" depth of cut without any difficulty. Anything greater than that would cause major headaches. With the retrofit, we are able to increase the DOC to 0.050" to 0.060" and maintain the feed rates, which range from 9 to 50 ipm." Spindle speeds are anywhere from 10,000 to 40,000 rpm, with higher speeds for machining aluminum.

King Machine

King Machine of Akron's retrofit of a Johnsford VMC with a Siemens Sinumerik 840Di control package allowed the Tier 2 supplier to reduce post-machining polishing of its tire molds.

Snodgrass added that the Siemens CNC increased the VMC's overall efficiency 30 to 50 percent. "The flexibility of the control helped out tremendously, as well as the advent of new digital drives and motors that allowed state-of-the-art technology to be retrofitted on an existing piece of iron," Snodgrass said. "The machine's performing a lot better than I ever expected. The only drawback to this retrofit is that we still have to use the old box ways, which limits our maximum rapid-traverse speeds. But, overall, that's insignificant."

The constant-stock principle

'High-speed machining" is often touted as a technique for reducing or eliminating manual polishing of molds. But HSM has become a buzzword that is losing whatever specific meaning it may have originally had, said Steve Piscopo, business development manager for die and mold products at Sandvik Coromant Co.

Piscopo tells customers of the Fair Lawn, N.J., toolmaker to think of machining the components from start to finish with HSM in mind. "That doesn't necessarily mean high cutting speeds and feeds for all operations," he explained. "Often it is still more practical and productive to rough with conventional techniques."

For instance, when roughing, material should be removed with consistent cutting parameters to leave the workpiece in good geometrical form for the subsequent tools, which usually have smaller diameters. "The principle of 'constant-stock removal'—machining with constant widths and depths of cut, tools properly selected for the job and toolpaths that leave the tool in contact with the workpiece for long periods rather than machining with a lot of tool entrances and exits—is a fundamental HSM idea," Piscopo said.

When finishing or superfinishing hardened tool steel, HSM prescribes not only consistent but relatively shallow cuts. According to Sandvik Coromant's *Die & Mold Making Application Guide*, "The cutting depths should not exceed 0.008" for widths and depths of cut. This is both to avoid excessive deflection of the holding/cutting tool and to keep a high tolerance level and geometrical accuracy of the machined die or mold."


Sandvik Coromant

Having each tool remove an evenly distributed amount of stock ensures high productivity, improves part quality, shortens the production costs and lead times, and reduces or eliminates the need for manual polishing. In addition, the cutting speed and feed rate will be at constant high levels when the radial depth of cut/axial depth of cut is constant.

Piscopo also recommends specific toolpath types, such as ones for "contouring" or "Z-level" machining instead of ones for "copy" or "lace" machining. They help maintain and properly form the desired part geometry.

Sandvik's guide states: "If, for example, using a programming technique in which the main principle is to 'slice off' material with a constant Z-value, using contouring toolpaths in combination with down (climb) milling, the result will be a considerably shorter machining time, better machine and tool utilization, improved geometrical quality of the machined die or mold and less manual polishing and tryout time."

Piscopo added, "The constant-stock technique is essential during semifinishing and finishing, when the goal is to minimize or eliminate manual polishing."

A determined finish

A moldmaker that determines the needed level of surface finish from the get-go and doesn't specify too fine a finish for the outsourced mold-polishing service or the moldmaker's in-house bench crew can increase throughput and cut costs. This is because the finer the finish the longer the time needed to manually impart it after machining.

"Cutting time on the polishing process is almost impossible," said Walter Fredrychowski, owner/operator of W.F. Polishing. "You can't cut corners. You need to put in the work to get the required finish."

The Saegertown, Pa., polisher primarily uses an ultrasonic machine to

Mold Finish Guide

SPI Finish	Material Guide
A-1	Grade No. 3 diamond buff
A-2	Grade No. 6 diamond buff
A-3	Grade No. 15 diamond buff
B-1	600-grit paper
B-2	400-grit paper
B-3	320-grit paper
C-1	600 stone
C-2	400 stone
C-3	320 stone
D-1	Dry blast No. 11 glass bead
D-2	Dry blast No. 240 oxide
D-3	Dry blast No. 24 oxide

Source: The Society of the Plastics Industry

finish molds. His arsenal also includes a lesser-used die profiler. "It was good in its day," Fredrychowski said. "I use it once in a while for aluminum parts to produce an A-1 finish."

Although average surface roughness is appropriate for determining the finish of machined parts, it isn't suitable for the plastic parts produced by the molds. Typical mold finishes are designated by the letters A through D, accompanied by a 1, 2 or 3. The finest is A-1.

Fredrychowski explained that dry blasting with oxides or glass beads produces D-grade finishes, ceramic stones generate C grades, B grades are achieved with grit paper and diamond buff compounds are used for the highly polished A grades. Specifying the correct finish is the tricky part.

Knowing what part the mold will produce and its color helps determine the needed finish. Fredrychowski said molds for producing clear plastic parts are the toughest. "Any mark on the mold will show up on the part. It's touchy."

Fredrychowski emphasized that the finish should be only as fine as it needs to be. "A higher polish equals more time, which equals more money," he said.

Harry Raimondi, technical service manager for Bales Mold Service Inc., Downers Grove, Ill., added that if a molded part doesn't need a fine finish, don't spend the money.

"Some [moldmakers] spec an A-1 or A-2 diamond finish when an A-3 would be OK," he said. "Many want the mold to look nice, even when the parts it's producing don't need that level of finish. Sometimes a mold doesn't even need polishing."

Raimondi suggested setting up a checklist that covers the part being molded, the required finish and the needed coating, if any.

"You may need to mold glass-filled resin parts, so you would need a finish that allows a hard chrome coating," he explained. "The ultimate coating needs to be considered from the beginning. Polishers are the last to touch a mold, and many moldmakers expect the polisher to bail them out."

Although many moldmakers perform polishing in-house, Raimondi estimated up to 80 percent send their molds out for polishing and/or plating. "Many can't afford in-house polishers."

Some moldmakers feel they have a higher level of control by keeping the polishing process in-house, but Raimondi noted that a moldmaker can retain control through effective communication with the polisher.

To aid in the communication between a mold-polishing service and its customers when specifying finishes on drawings, the Moldmakers Division of The Society of the Plastics Industry Inc., Washington, offers a mold finishing guide. It includes a reference sheet and a sheet of acrylonitrile-butadiene-styrene plastic with the 12 most common finishes on the front and, on the back, a guide to the specific material to impart each finish into the cavity of 420 stainless steel at a hardness of 50 HRC.

SPI notes that the finish will vary depending on the plastic material of the part the mold produces, as well as the combination of steel types, resin types and processing parameters.

Whether the mold is electrical discharge machined or milled, or the work is completed in-house or outsourced, minimizing or eliminating mold polishing can pay big dividends. But only through proper planning can the cost- and time-savings objectives be met.

"Polishing is the last thing done," Raimondi said, "but it shouldn't be the last thing you think about."

The following companies contributed to this report:

Bales Mold Service Inc.
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GE Fanuc Automation Americas Inc.
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www.gefanuc.com

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