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New CAM Feature Halves Roughing Time

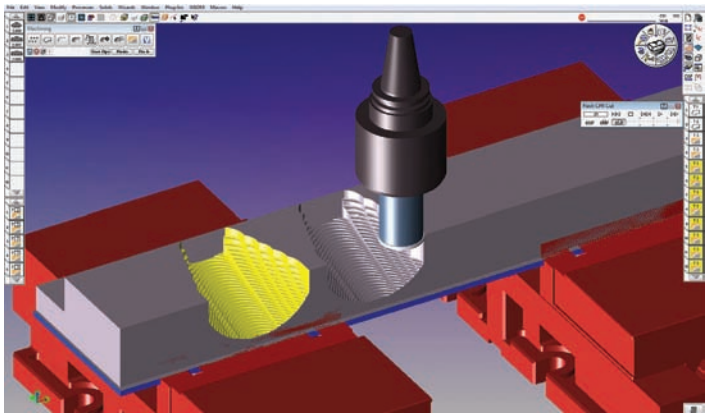
While common in mold shops, plunge milling traditionally hasn't been as popular among manufacturers of discrete parts. That's because unlike molds and dies that require hogging out large volumes of material—for which plunge roughing is ideal—discrete parts are often machined from castings supplied in near-finished form. However, amid the increasing prevalence of custom work and the development of cutting tool designs for specialized applications, more discrete-parts manufacturers are turning to this technique in order to achieve new levels of efficiency.

CAM developer Gibbs and Associates (Moorpark, California), a Cimatron company, cites two customers as examples. At Norfolk Specialties, GibbsCAM's plunge roughing routines have cut machining time in half and quadrupled tool life. The second shop, Ouverson Engineering and Machine, enjoys similar benefits. On one job, for example, the technique improved tool life by approximately 88 percent and halved cycle time.

Both shops are located in the Midwest, both are buried in work despite a dismal, uncertain economy and both have benefited from plunge roughing, but their operations are quite different. Based in Norfolk, Nebraska, Norfolk Specialties makes replacement parts for foreign-made, outdated or unsupported equipment in various industries, including medical, food, rubber and steel. For this 14-man shop, a typical job involves reverse engineering a broken component to produce one or two parts. "Most customers are repeat customers, but we seldom get repeat parts," says Dan Wilson, machinist and programmer. "These one- or two-part orders keep us busy for a 9-hour shift, five days a week, and if we want more hours, the work is available."

Four hundred miles away in Milaca, Minnesota, Ouverson Engineering and Machine (OEM) produces heavy-duty axles and axle components for monster truck and mud-bogging professionals and hobbyists. The three-man shop supplies sports truck drivers across the globe who use the military's 2.5-ton Rockwell top loader axle. Notable customers include professional monster truckers Tom Meents, driver of "Maximum Destruction," and Dennis Anderson, driver of "Grave Digger." Orders are shipped

Jed Millikan, Norfolk Specialties, cleans these "clamp bars" after plunge roughing and finishing surfaces on a Milltronics RH30. Plunge roughing removed 278 pounds from the 665-pound, 4140 pre-hardened billet. Eight more operations – including drilling, boring, counterboring, countersinking and tapping holes at various angles – remove an additional 60 pounds, resulting in a finished component that weighs half as much as the raw stock.



At Norfolk, GibbsCAM's plunge roughing routine has cut on-machine time in half and quadrupled tool life.

NORFOLK SPECIALTIES, OUVERSON ENGINEERING

PROBLEM Rough milling parts requiring extensive metal removal created a production bottleneck

SOLUTION Plunge roughing routines in GibbsCAM software from Gibbs and Associates

RESULTS Improved cycle time and tool life, reduced machine wear

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Like this finished C, many Ouverson axle components are perfect candidates for plunge roughing. Because much of the work is custom, castings are not an economical alternative to machining from a billet.

as far away as Australia and Guam, and for certain components, OEM is the only supplier on the planet.

Most parts at both Norfolk and OEM are either rush jobs or made in low quantities, so casting or other high-production, pre-machining processes would be impractical. Rather, the shops typically start with raw stock, most of which requires removing a massive amount of material. For example, one recent part at Norfolk involved removing 278 pounds of 4140 prehardened steel from a 665-pound piece of stock. The roughing stage often became a bottleneck, particularly on parts with irregular shapes.

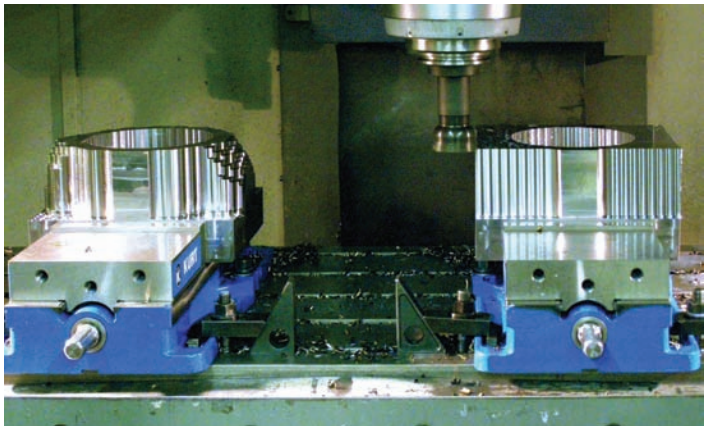
Both shops were able to alleviate this problem with plunge roughing because the technique removes material faster and places less wear and tear on cutting tools and machines compared to other roughing processes. Essentially, it involves taking a series of overlapping passes that cut into the workpiece along the Z axis, similar to a drill. This improves stability and makes the process less prone to chatter and vibration. Additionally, eliminating side pressure from X- and Y-axis forces by keeping all cutting forces in the Z axis enables deeper cuts and more effective use of lighter (less rigid) and/or older machine tools.

Norfolk machinist and programmer Dan Wilson was well aware of plunge milling's benefits before the shop started using the routine included in the latest version of GibbsCAM. In fact, he did his best to replicate the technique manually by programming his machines' conversational controls line-by-line with G and M codes. However, even the best conversational controls provide only drill cycles, which are restricted to straight-line motion. Plunge roughing, on the other hand, requires pulling the tool away from walls during retraction to avoid chipping or breaking the inserts. Nonetheless, Mr. Wilson says this method was still worthwhile on parts requiring massive metal removal despite the extra programming effort and tool costs.

Of course, it goes without saying that Mr. Wilson welcomed the software upgrade. "Until then, I thought SolidSurfacer would always be the most valuable function of GibbsCAM," he says. "Now, I think Plunge Rough has the highest payoff for us."

Mr. Wilson shares a single seat of GibbsCAM with several other machinists, who reserve the software for use on the most difficult parts. For simpler jobs, standard practice is using the conversational controls on the shop's Milltronics machines. "These machines have some of the best conversational controls, but if we have irregular surfaces or a lot of stock to remove, using GibbsCAM SolidSurfacer or Plunge Rough is more efficient," he explains.

Compared to the previous method, the CAM software's plunge roughing routine has cut programming time in half because the shop no longer needs to compute or select points for plunging. One recent job that previously would have required 6 hours of machining and $56 worth of inserts took only 3 hours and $14 in



A 2.5" Sandvik plunge mill roughs stock for a pair of Ouverson steering knuckles. The 18-pound final part is machined from a 190-pound block of 1018 plate steel. GibbsCAM Plunge Rough reduced roughing time from 1.75 hours to 45 minutes.

tools. Having realized these benefits, Mr. Wilson says the shop would use the software more often if machinists didn't have to share the workstation. With a growing need for rough machining, surface machining and rotary milling, Norfolk might consider investing in another seat, he adds.

While Mr. Wilson made an attempt at plunge roughing through manual programming, Randy Ouverson, owner of OEM, used fly cutting for roughing applications before the release of the latest version of GibbsCAM. In addition to lengthy cycle times, this strategy led to constant insert chipping and vibration that threatened to damage machines. "I knew that plunge roughing is popular for pockets, cores and cavities, but I hadn't considered it for my parts. It turned out to be a perfect application," he says.

Mr. Ouverson upgraded to the latest version of the software at the recommendation of his GibbsCAM reseller, which he consulted about a difficult steering component order. The challenging part was a custom knuckle that began as a 10-by-12-inch plate of 1018 steel measuring 6 inches thick with a 6-inch-diameter hole flame-cut through the center. The knuckle required a great deal of material removal—the 190-pound initial stock would be machined into a finished component that weighed in at only 18 pounds.

Two setups were required to machine the top and bottom of the knuckle. To rough the first side, the shop used a 2-inch-diameter end mill with 14 double-sided inserts mounted on a 50-taper Tree 1260 machining center. Even after adjusting feeds, speeds and cutting depths, roughing the first side took 2 hours. Chatter and chipped inserts resulted in tooling costs of $98 per part. Moreover, side pressure on the part led the shop to tighten the vise excessively, putting it at risk for damage.

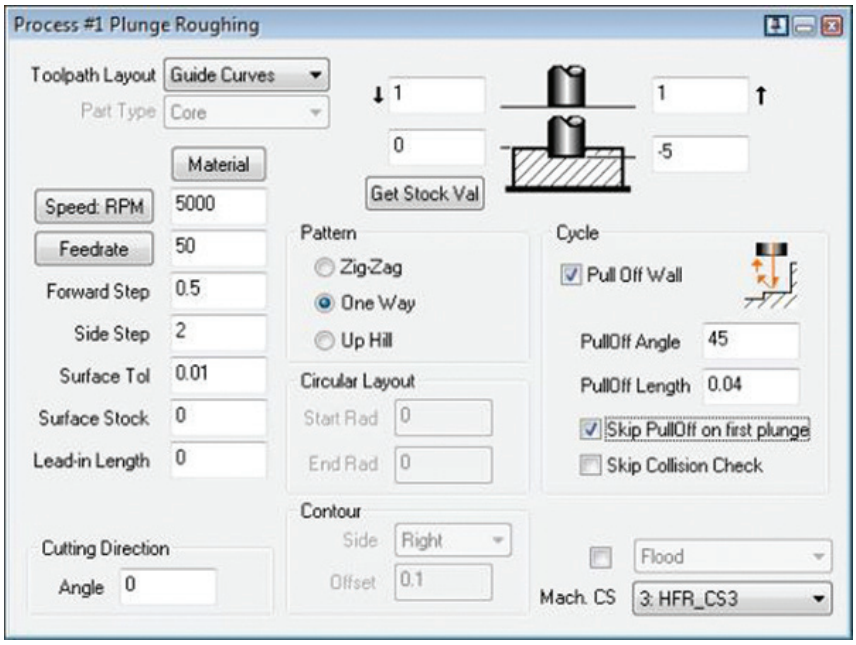
The shop had roughed only two of the parts this way before vibration loosened a fitting on the drawbar, preventing the release of the tool. However, with GibbsCAM's plunge roughing routine and a 2 $^{1}/_{2}$-inch-diameter, 4-inch-long Sandvik plunge mill running at 1,000 sfm and a chip load of 0.008 inch, the shop reduced machining time to 1 hour and tooling cost to $12 per part. "More importantly, I think it saved my machine," Mr. Ouverson says. "A side benefit we discovered is that corner radii cut cleanly with plunge milling, whereas fly cutting chirps, chatters and then chips the inserts."

Plunge Roughing: Overcoming Programming Challenges

As seen here, the latest version of GibbsCAM provides various options for performing a plunge roughing routine as efficiently as possible.

To the uninitiated, plunge roughing might not appear much different than drilling cycles. Essentially, the technique involves taking a series of overlapping passes that cut into the workpiece along the Z-axis, eliminating side pressure and directing cutting forces into the spindle.

However, belying the technique's simplistic outward appearance is the fact that it involves considerations far beyond drilling. According to software developer Gibbs and Associates, that's reason enough to carefully scrutinize any CAM software that purports to perform this technique. Outlined below are a number of factors that, according to the company, are essential for any CAM system's capacity for programming effective plunge roughing routines.



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BEYOND DRILLING

Unlike relatively simple hole-drilling operations, plunge roughing might involve surfaces that are angular, irregular or freeform, or that include a perimeter contour. These are all conditions that require special offsets for changing depth and direction. Not to mention that unlike a drill, the cutting tool cannot retract along the same path used to cut into the work. Rather, the tool must pull away from the cut first to avoid hitting the stock and chipping the inserts.

Of course, it might be worthwhile to attempt plunge roughing via a drill cycle without CAM software if certain conditions are met: if programmers have the time and patience to calculate locations and program pull-off motion before every retraction, if the volume to be cleared is large, and if the surface is flat and parallel to the X-Y axis. Another factor to consider is whether such a programming effort can be amortized over a large number of parts. Otherwise, however, shops would be better served by CAM software that can handle all the roughing situations they are likely to encounter while minimizing programmer effort, the company says.

THE MINIMAL REQUIREMENT

According to Gibbs, the lowest common denominator for any plunge-roughing CAM software is the ability to automatically generate pull-off motion before retraction, as mentioned above. This will protect the cutting tool and enable rapid motion between plunges. It will also protect the workpiece if plunge roughing is used to get very close to final finish. Allowing the user to specify pull-off distance (angle and length) provides allowance for center-cutting tools, straight inserts and angled inserts so that pull-off is as fast as material and tool conditions permit without inserts rubbing and chipping at the bottom of the cut.

CONTAINMENT AND BOUNDARIES

Even with workpieces that are completely flat, CAM software must permit users to identify stock and containment regions or boundaries to restrict the plunge tool in depth and lateral motion. The software should specify cutting regions similarly to the way it handles surfaces, the company says. While this is relatively simple for 2.5-axis machining, 3-axis work is more of a challenge. Ideally, the software would provide easily selectable methods to define the extent of the volume to be roughed. This includes surfaces to define the bottoms of cuts, geometry to define surfaces above which roughing should be excluded, and stock or other already available geometry to define where rapid moves need to shift to the programmed feed rate.

CUTTING DIRECTION AND PATTERNS

Another consideration is that CAM software should have the flexibility to allow various cutting directions, the company says. At minimum, it should enable straight-line nibbling along a user-specified angle. A drill pattern, for example, would provide a grid of points within a containment area.

Circular motion is desirable when plunge roughing is performed as a face operation on any type of turning machine, and, for efficiency, when a shape requiring roughing on a mill or machining center is closer to a circle than a rectangle. This requires the ability to specify beginning and ending radii, to prevent time wasted programming plunges along individual radial lines from center to edge and back. A contour pattern provides plunging along a curve or section of geometry with a given offset. Perhaps the most valuable capability is the capacity to define a pattern by selecting an area between two curves. This permits roughing without specifying an entire closed area.

ALTERNATING DIRECTION

Software that enables alternating directions between plunge passes to minimize travel can provide additional efficiency, the company says. That way, when plunging is complete along a line or circular motion, the tool moves into the closest, un-roughed area and begins moving in the opposite direction. This would consist of alternating, zig-zag passes for a linear pattern and alternating clockwise and counter-clockwise for a circular pattern.

CAVITIES AND CORES

CNC programmers can save a lot of time if the CAM system allows for both cavities and cores, and if it can easily move from the inside out or outside in to accommodate standing and sunken features equally. According to Gibbs, these capabilities eliminate the need to waste time creating additional containment geometry to "fool" the software.

OFFSETS AND PULL-OFF DIRECTION

For freeform or complex geometry, the software should be able to compensate for changes in direction when determining offsets and pull-off direction. Otherwise, the programmer will be severely restricted, the company says. As a simple example, it cites a domed surface where plunging begins going uphill. Upon reaching the top, the tool should not proceed. That's because pulling off from any plunge beyond the top of the dome would push the tool into the workpiece, while pulling off in the other direction would drive the tool into deeper uncut material and possibly damage it.

The situation is similar with the mirror or mold image of this geometry. In that case, plunging must begin at the bottom, either with preliminary drilling to open the space for a plunge mill or beginning at the lower point with a center-cutting plunge mill, which then moves up toward the top of the dome so that it can pull off into cleared space. For this type of scenario, the software should also provide the option to begin clearing an area that will be concave with a drilled hole—as long as plunging is not done with a center-cutting tool.

CHANNELS AND ISLANDS

Tight areas can cause problems for inadequate software, the company says. For example, when plunging between islands or to create a channel, the pull-off before the stepover should not gouge an adjacent island or opposite wall.

THE OVERRIDING FACTORS

All of these challenges should be considered by shops that are considering plunge roughing but don't have CAM software with special motion and flexibility required to use the process efficiently. The company says the latest version of its GibbsCAM software incorporates new plunge roughing routines that take all these issues into account, as evidenced by the two shops Norfolk and Ouverson, who recently implemented this technique.

Of course, various software packages address these challenges in different ways. According to Gibbs, the most important considerations are ease of use and flexibility for the user. After all, the whole purpose of plunge roughing is to save time. ■

For more information from Gibbs and Associates, a Cimatron Company, please visit www.GibbsCAM.com or call: 805-523-0004.