STAYING SHARP

BY MIKE PRINCIPATO

Nothing but net (value)

Let's get something straight: The notion that shop management software can truly manage anything in your shop is pure baloney.

My contention at the unofficial birth of such software—way back in the '80s, when PCs were the size of VW Beetles and roughly as fast—has always been that managers manage, using an arsenal of appropriate tools, including technology, to optimize and enhance their inimitable human adaptation and communication skills.

Readers know I'm far from being a technophobe. On any given day, I'm what tech industry geeks call an "early adopter" of the newest products, under one condition: The new product, whether hardware, software or Web-based, has to have net value to me. Simply put, the gadget or program has to generate more profit or life quality for my business or me than it costs in energy, time or money.

All the real-time floor reports, bar code imprinting and onboard tooling inventory in the world won't mean bupkus to you and your management team if you need to adapt your winning business practices to your new software.

Case in point: About 3 years ago, the personal digital assistant was the "must have" tech accessory among the business cognoscenti. Trouble was, if you asked a PDA devotee a simple scheduling question like, "Wanna have lunch Thursday?", by the time he powered on, punched up, scrolled down and pecked in the date, it was already Friday. I kept my paper-based planner, never missed an appointment and enjoyed the scorn of the technology lemmings who labeled me a Luddite.

That was until the Palm Treo emerged 2 years later, which I promptly bought because it allowed me to ditch my planner, cell phone, pager and even, at times, my laptop. Now that's creating net value.

Roughly 25 years after the introduction of the first off-the-shelf shop software, the packages have gotten better—a lot better. But many early adopters of products that over-promised and under-delivered got burned, while those who waded more cautiously into the murky waters of shop floor estimating, scheduling and accounting software have typically benefited from their prudence.

That said, too many shop managers continue to make the same mistakes they made years ago when choosing or upgrading shop management software. They fall prey to companies whose products don't live up to their marketing hype. They insist on buying superfluous features they'll never use. And, worst of all, they don't do their due diligence before selecting a product that will have a profound impact on their business for years to come.

Look, I'm a marketing guy who appreciates the need for a certain amount of puffery when peddling shop management software. But some of the claims made by industry vendors are positively Barnumesque, ranging from "this software will pay for itself in 1 year" to "implementation is so simple you can do it yourself." If a prospective vendor makes these kinds of claims, run away—fast. Software implementation or upgrading is never as streamlined or simple as you expect.

Nor should you expect to use all or even half of the features of the software you're acquiring, especially if you're converting from a pure paper-based or hybrid paper/computer-based system. Focus only on the features that matter to you relative to the way you run the shop now and the way you expect to run it during the next 5 years.

For example, if you're a numbers guy who routinely drills into actual vs. estimated job costing, choose a software application that simplifies that task and the related accounting functions. If your shop produces complex assemblies and needs to share drawings and data across the floor and throughout the process, look for that capability. All the real-time floor reports, bar code imprinting and onboard tooling inventory in the world won't mean bupkus to you and your management team if you need to adapt your winning business practices to your new software. It should be the other way around.

Finally, for the love of God, man, exercise due diligence. Some shop managers spend more time researching their next car than they do evaluating business software. But I can assure you that even a Ferrari will be cheaper in the long run than a bad software purchase. Any worthwhile software vendor provides, at a minimum, an online demo of its products. Gather your key people in a room with a speakerphone and an Internet connection and set aside 1 hour for each demo. Firmly instruct each prospective vendor to focus on the applications that matter to your business. After each demo, discuss with your team their reactions to the software. Once the demos are complete, choose your two top prospective vendors and schedule more comprehensive, on-site demonstrations and discussions with each.

By the end of the process, you'll know whether you're investing in software that will produce net value for your business or the shop equivalent of a late-'90s PDA—the answer to a question nobody asked.

About the Author

Mike Principato owns a machine shop in Pennsylvania. He can be e-mailed at ctemag1@netzero.net.

Disc grinding

Disc grinding machines grind flat surfaces using an abrasive wheel, or pair of wheels, known as discs. The discs are mounted against steel machine plates. The mounting, or back, side of the disc contains molded-in, threaded nuts or a steel plate with threaded holes for mounting. The discs typically range from 300mm to 1,000mm in diameter.

Two main types of disc grinding machines are available: single disc and double disc. Single-disc grinding machines are for parts that only need to be ground on one side or when higher accuracy is required, even if the part needs grinding on both sides. Double-disc grinding machines are for grinding two flat, parallel surfaces in one pass. The parts usually require an equal or semi-equal amount of material removed from both sides. Although not as accurate as single-disc grinding, double-disc grinding reduces handling and speeds production.

While almost any type of part or material can be ground on both types of disc grinding machines, the main application is automotive parts, such as those used in engine and transmission blocks and housings.

Single discs can be mounted in a vertical or horizontal spindle. In a single-disc machine, the part is most often mounted on a rotary table. A part rotates under the disc and the disc comes down and grinds it.

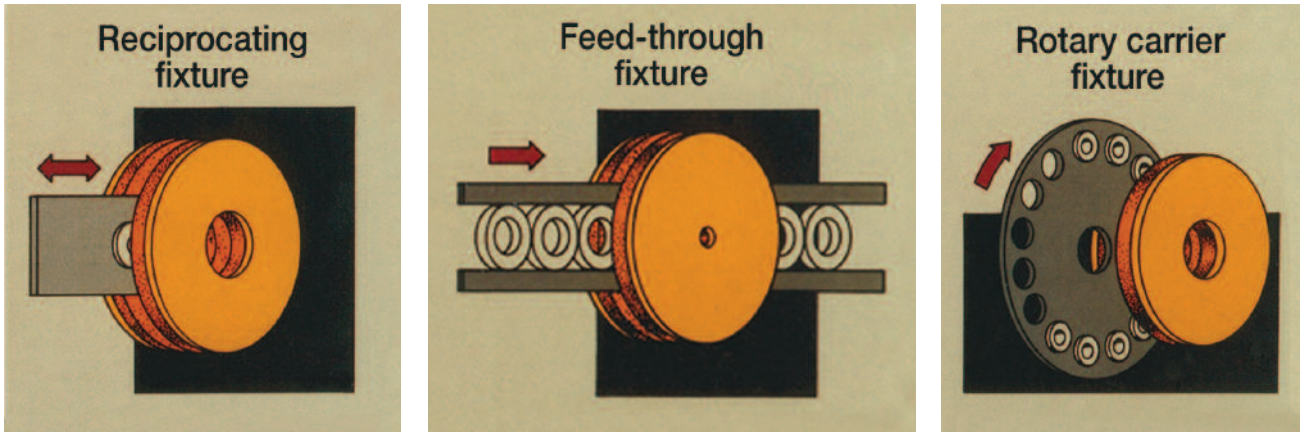
On a double-disc vertical machine, one spindle is arranged on the top and one is on the bottom. Parts are held horizontally in a fixture that rotates between the upper and lower discs. On a double-disc horizontal machine, the spindles face each other, one on each side. In this case, the parts are positioned vertically in the fixture.

Deciding between using a vertical and horizontal configuration depends on how the parts are presented to the machine. It is simple to present a stack of flat parts to a vertical machine, while a horizontal machine often requires reorientation and, thus, complicates handling.

With double-disc grinding, the part is fed between two discs in a feed-through, rotary-feed or reciprocating-feed fashion. With feed through, the parts are supported throughout the process by guide rails above and below. The parts usually are fed by belts into the machine and between the two discs. The alignment of the guides relative to the disc position is a determining factor in how the parts react as they pass through the grind zone and how stock is removed. Throughout the entire process, each part is driven by the part behind it through the grinding zone. The discs are tilted such that the narrowest point is at the exit. Therefore, as the parts advance, they are ground progressively thinner until they exit.

With rotary feed, the parts are mounted on or in some type of carrier that passes between the two discs. The drive of the carrier pushes the parts through. Normally, the carrier is a plain disc with multiple openings to accommodate the part periphery. Again, the discs are tilted such that the narrowest point is at the exit.

Reciprocating feed is more specialized. With this method, a plunge-grind cycle is used to bring the parts to size. Parts are held in a workholder "paddle" and reciprocated between the two discs as the discs plunge-cut toward the reciprocating part to remove stock. On a reciprocating-feed machine, the discs are not tilted; they are parallel to each other and the carrier.



Landis Grinding

The three types of feeds used with double-disc grinding: reciprocating, feed and rotary.

Feed-through machines provide the highest production rates, followed by rotary feed machines; reciprocating-feed machines offer the lowest production rates. Accuracy is just the opposite. With reciprocating feed, a flatter part can be obtained than with the other two methods.

Disc grinding provides dimensional tolerances often better than 0.0002" and surface finishes of 16 R_a or finer on aluminum and 8 R_a on ferrous alloys.

Special thanks to Andrew Rovelstand, Gardner R&D manager of Landis Grinding Systems, Waynesboro, Pa. For more information about the company's disc grinding machines, visit www.landis-us.com, call (717) 762-2161.

Make 'em look good

BY JAMES A. HARVEY

Why do we want our parts to look good? One answer is we usually have to sell them. Parts that have a skillfully made appearance are nearly always more accurate, more consistent and easier to sell than carelessly made parts.

People may argue that appearance shouldn't matter as long as parts are in tolerance. However, ragged parts can be difficult to inspect to determine if they are in tolerance. Here are some suggestions to help you produce attractive, quality parts without sacrificing much time.

■ Apply a fly cutter to produce smooth surface finishes.

I've heard it said that "anybody who uses a fly cutter is not a real machinist." This is a vague and simplistic statement, and I disagree with it. Advantages exist to using a fly cutter.

First, a fly cutter lasts forever. When the cutter becomes dull, it is a simple matter to manually sharpen one edge or tip. Second, it can be adjusted to match the part's width. Third, it imparts a fine finish.

The disadvantages to applying a fly cutter are the tool is generally less rigid than other cutters and, to get a nice finish, the feed rate has to be relatively low.

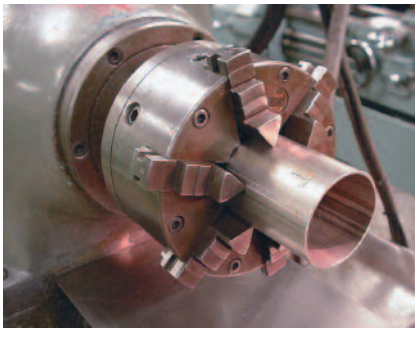
Bear in mind that because a fly cutter is normally used as a finishing tool, a lower feed is not a great disadvantage. Most tools need to be fed slower when finishing than when roughing or semifinishing.

When cutting steel with a fly cutter, I prefer to use a tool with a relatively small tip radius, say, 1/32". A 1/32" radius cuts with fairly low pressure, yet leaves a fine finish. If the radius is much smaller, the cutter may leave pronounced feed marks on the part. If the radius is much larger, the increased cutting pressure caused by the large contact area may cause excessive tool deflection and chatter.

■ Avoid side milling when possible.

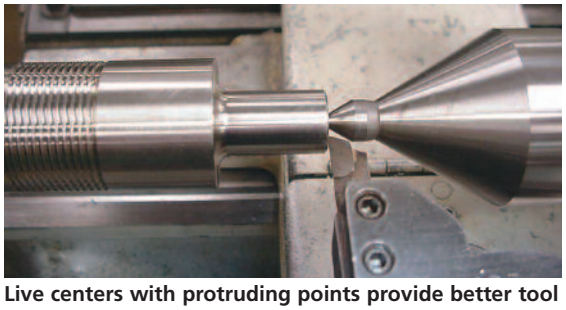
A face-cut surface almost always looks better and is usually flatter than a side-cut surface. The reasons are because a side-milled surface is prone to more ailments than a face-cut surface. The finish of a side-milled surface is based on, among other things, the condition of the cutting edges along the length of the endmill. If the endmill has some nicks, then it may leave tracks on the part's surface.

In addition, a long endmill almost always flexes as it nears the bottom of a thick part.



All images: J. Harvey

A 6-jaw chuck, which is ideal for holding lathe work, spreads clamping pressure over a greater area than a 3-jaw chuck.



Live centers with protruding points provide better tool clearance when working near the tailstock.

Another factor is endmill taper, which is more common with reground endmills. Whatever taper an endmill has will show up in the part. Sometimes, the additive effects of tool flexing, nicks and taper produce quite an inaccurate, lousy surface finish.

When side milling can't be avoided, use a new or resharpened endmill to finish the pocket.

■ Use a 6-jaw chuck in a lathe for gripping a finished surface.

Sometimes, you are forced to grip on a finished surface to machine other features of a part. A 6-jaw chuck spreads clamping pressure over a larger area than a 3-jaw chuck and reduces the possibility of damaging the surface. Also, a 6-jaw chuck doesn't distort thin-walled parts as readily as a 3-jaw chuck.

Some machinists use small aluminum or brass pads between the jaws of a 3- or 4-jaw chuck and the workpiece to protect a finished surface. I would rather use a 6-jaw chuck and take light cuts to avoid putting a lot of pressure on a finished surface.

■ Prepare larger pieces of raw material with an orbital sander.

Sheet stock usually arrives from the vendor with a variety of nicks, scratches and other undesirables. Orbital sanding is a great way to prepare sheet stock for machining. Use 120- or 180-grit sandpaper, which effectively cleans a surface and leaves a smooth finish.

■ Use live centers.

Unless you're turning at a snail's pace, dead centers have a tendency to heat up and gall—in spite of whatever miracle grease you apply.

Live centers work well and there is a variety to choose from. I prefer live centers with small protruding points because they augment tool clearance.

About the Author

James A. Harvey is a machinist and plastic-injection-mold maker based in Garden Grove, Calif. He can be e-mailed at HarvDog42@aol.com. Machining Tips is adapted from information in his book Machine Shop Trade Secrets: A Guide to Manufacturing Machine Shop Practices, *which is published by Industrial Press Inc., New York. The publisher can be reached by visiting www.industrialpress.com or calling (212) 889-6330.*

Shooting for top performance

BY BILL KENNEDY, CONTRIBUTING EDITOR

Few manufacturers can tout the accuracy of their precision metal parts in terms of thousands of yards as well as thousandths of an inch. One that can is Lilja Precision Rifle Barrels Inc., Plains, Mont.

Lilja makes rifle barrels for hunters, law-enforcement and military personnel, and competitive target shooters. The barrels are known for their extreme accuracy. U.S. marksman Matthew Emmons used a .22-caliber Lilja barrel fitted to a target rifle to win a gold medal at the Athens 2004 Olympic games.

The barrels handle extreme power too. Military sniper rifles fitted with .50-caliber Lilja barrels have proven effective at over 2,400 yards, and the Lilja Web site cites a case where a few .50-caliber rounds fired from a U.S. Coast Guard helicopter disabled the engines of a fleeing drug-runner's speedboat.

Lilja recently machined a group of .50-caliber barrels for the Coast Guard from 1¾"-dia., 4140 chrome-molybdenum steel bar stock with a hardness of 28 HRC. Lilja receives the stock, which is specially formulated for rifle barrels, from Republic Steel in 40,000-lb. shipments of 20' bars. "Some of the chemistry is a little different than garden-variety 4140," said company founder Dan Lilja.

Lilja makes the majority of its barrels from stainless steel, which offers high resistance to heat erosion, the major cause of barrel wear. But the most significant wear mechanism for .50-caliber barrels is friction between the bullet and barrel, and the 4140 alloy provides longer barrel life than stainless.

Lilja doesn't make finished rifles; each machined barrel goes to a gunsmith who cuts off and "crowns" the muzzle, reams a bullet chamber on the other end, and threads the barrel before fitting it to the rifle's action and mounting the arrangement on a stock. To provide material for the gunsmith to work with, the barrels are machined at least 1" longer than the length at which they'll ultimately operate. For the .50-caliber barrels, which have a 28" design length, Lilja cuts the bar stock to 30" before machining.

The first machining operation is drilling the barrel bore, performed on a Pratt & Whitney deep-hole drilling machine with a Drill Masters 0.494"-dia., carbide-tipped gundrill that features a general-purpose N8 nose profile. The drill is stationary while the machine spins the bar at 2,500 rpm and feeds it at 2 ipm. Drilling the 30"-long bore takes about 15 minutes.

Lilja then reams the barrel on a custom machine, using a Pacific Tool & Gauge special 0.500"-dia., carbide reamer. Run at 500 rpm and 6 ipm, reaming requires about 5 minutes to finish a barrel to a tolerance of ±0.0005".

Next is the rifling process, which produces helical grooves and lands that run the length of the barrel's ID. The lands are formed so their ID is smaller than the bullet's OD. In this case, the barrel's 0.500"-ID lands grip the 0.510" OD of the .50-caliber bullet and cause it to spin as it travels through the bore. The spin stabilizes the bullet in flight like a well-thrown football.

A number of ways exist to rifle a barrel. One method is to cut the grooves and lands with a single-point tool or multiple-tooth broach. In hammer forging, a die in the shape of the desired rifling profile is put inside the bore and powerful hammers pound the barrel's OD to conform the ID to the die. Some rifling is also done via EDMing.

Lilja said a key factor in a barrel's accuracy is rifling uniformity, and he believes maximum uniformity is achieved through button rifling. In button rifling, an oversized, football-shaped carbide tool, or button, with helical grooves, is drawn through the barrel to cold-form the grooves and lands. For the .50-caliber barrel, the button has a maximum diameter of 0.514" and produces six lands and six grooves that twist one full rotation every 15" of barrel length. Aided by a lubricant, a hydraulic cylinder pulls the button through the 0.500"-dia. bore. Button rifling consumes about 1 minute.

Cold-form rifling creates stresses in the barrel, which can cause it to change shape during later machining operations or when subjected to the heat of a bullet. So, after rifling, Lilja has the barrels stress-relieved by a commercial heat-treatment provider. In a vacuum furnace, grouped in lots of about 120 pieces, the barrels are subjected to temperatures of 1,100° F for about 2 hours to relieve residual stresses.

Next, the barrel is lapped, an operation Lilja said is crucial to barrel accuracy and life. Lilja casts a custom-fit lapping tool by pouring molten lead around a rod set inside the barrel. The lead conforms exactly to the shape of the profiling of the rifling and contracts as it cools to leave a 0.001" clearance between it and the rifling profile. Using a lapping compound, the lapping tool is hand-stroked through the barrel to polish it. From time to time during the process, the lapping tool is withdrawn, the lapping compound is cleaned from the barrel and the bore is visually inspected with a video borescope. The inspection takes place three or four times during lapping, more often toward the end.

Lapping typically consists of hundreds of strokes of the tool

Lilja Precision Rifle Barrels

This .50-caliber rifle barrel measures 1¾" in diameter and 30" in length, which provides extra material for the gunsmith to work with when producing the finished rifle. A finished barrel is 28" long.

and consumes about an hour. Lapping marks on the lands are parallel to a bullet's path, as opposed to the perpendicular marks that result from machining the barrel. This reduces friction on the bullet and minimizes fouling of the barrel, which is caused when material rubs off the bullet as it passes through the barrel.

With the internal work complete, Lilja contours, or tapers, the barrel's OD to produce a smaller diameter at the muzzle end than the chamber end. Contouring is done to lighten the barrel, but it also reduces rigidity and, thereby, accuracy. Therefore, a barrel intended for target shooting is contoured less than other barrels. Previously, Lilja contoured the barrel on a manual tracer lathe, but now counters it on a CNC TS Harrison & Sons lathe, using a Kennametal coated TPMR-321 insert run at about 1,600 rpm and 0.010 ipr. Contouring takes about 10 minutes.

After contouring, the company grinds the barrel on a Stephen Bader Co. belt-type, centerless grinder for about 1 minute. The result is "the equivalent of a nice, smooth 300-grit finish. We don't hold any dimensions with it; it's more of a polishing operation," Lilja said.

The final machining operation is milling six longitudinal flutes to further lighten the barrel and increase its surface area to aid cooling after a bullet is fired. Milling is done on a Supermax vertical machining center. The barrel's chamber end is clamped in an 8"-dia., 3-jaw chuck mounted on an indexing fixture, while the muzzle end is held in a tailstock. Approaching the barrel from the side, Lilja cuts the flutes with a Pacific Tool & Gauge special Woodruff-style carbide cutter, run at about 400 rpm and 2 ipm. Fluting takes about an hour.

Lilja typically makes .50-caliber barrels in groups of 10 to 50 pieces. The majority of the company's work is made to order and has a lead time of about 8 weeks.

For more information, contact Lilja Precision Rifle Barrels Inc. at (406) 826-3084 or www.riflebarrels.com.

Courting the middle

BY GREGORY FARNUM
AND DAVID GEHMAN

The past year has brought numerous product enhancements from CAD vendors. As is usual with software, these may appear to be a confusing mass of acronyms, jargon and hyper-excited claims. To help guide you through this jumble, we have surveyed the field, isolating key releases and teasing out themes that may prove useful when planning your CAD strategy and purchases.

Arguably, the biggest news on the CAD front is the release of Autodesk Inc.'s AutoCAD 2006. This is because so many small- to medium-sized metalcutting shops—shops that will probably be pleased with the latest version of this old standby—are AutoCAD users.

Arguably, the biggest news on the CAD front is the release of Autodesk Inc.'s AutoCAD 2006. This is because so many small- to medium-sized metalcutting shops—shops that will probably be pleased with the latest version of this old standby—are AutoCAD users.

In this latest release, AutoCAD has beefed up its 2-D drafting capabilities with a number of features that boost functionality and, the San Rafael, Calif., software developer stresses, save time. Chief among these are enhancements to its "dynamic blocks." Blocks are basic objects in frequent use, such as a bolt. AutoCAD 2006 adds special grips that enable users to manipulate and change these objects. Additionally, the blocks now have a parametric aspect that automatically adds associated part features as the block is changed. A wizard for extracting data has been added that automatically captures data from the blocks and places it in a customizable table to aid in calculations and the creation of part lists.

AutoCAD's hatching capabilities have been enhanced, in that they can hatch multiple areas simultaneously and quickly calculate their areas, with the results being displayed within the drawing. Also, the software has an improved engineering calculator—again, another timesaver.

Inventor 10, AutoCAD's 3-D modeling software, was unveiled at the same time and now includes "Functional Design." This permits quick creation of common parts through the use of a parametric interface. This latest version of Inventor also automatically generates and maintains a bill of materials. AutoCAD offers a migration path to Inventor.

Upgraded, too, is Autodesk Vault. Included in all Autodesk manufacturing design products, Vault is Autodesk's product data-management tool. As noted in a previous column, PDM denotes software designed to store essential product data and make it available throughout the organization. It does this by holding all the master design data and other key product information in a single location—a secure "vault."

Folks in other parts of an organization can quickly access this data, but changes they make to it are monitored and recorded, assuring the integrity of the original design data while facilitating its use by manufacturing, purchasing and marketing. (Some software companies use the term PLM—product life-cycle management.) The new version of Vault allows complete assemblies to be copied and automatically assigned new part numbers. In addition, Vault is now integrated with Microsoft Office, allowing the business side of the organization to access key data.

This fall, Plano, Texas-based UGS Corp. released Version 18 of Solid Edge. In addition to various performance enhancements to its Solid Edge product, the release included an array of tools intended to simplify the migration from 2-D to 3-D design.

UGS also introduced its Velocity series. Aimed at the midmarket (i.e., smaller shops), the series offers scaled-down and more-affordable versions of the high-end Solid Edge technology, including Teamcenter Express. Teamcenter Express is PDM in a box, a quick-to-install and relatively easy-to-learn system for midsized manufacturing companies that integrates with Solid Edge but supports other CAD products as well. It can also be scaled up to UGS's full-blown Teamcenter, a sophisticated PLM system.

Parametric Technology Corp.'s Pro/Engineer is practically synonymous with high-end CAD, but Needham, Mass.-based PTC, too, is courting the midmarket. The entry level Pro/E Foundation package can be had for about $6,000, and users can take advantage of Pro/E's scalability to upgrade in the future. Additionally, PTC offers Windchill On Demand, an IBM-hosted version of its highly regarded Windchill PDM product. It enables users to embark upon PDM with minimal investment.

Finally, this year IBM added PLM Express for Industrial Products and Consumer Goods to its line of PLM Express products. Aimed at firms with 100 to 1,000 employees, this PLM solution is surprisingly powerful for the money, a sweet deal made sweeter by the availability of IBM services and financing options. For users who may eventually wish to upgrade their PLM functionality, a series of add-ons can be had for additional cost.

At the moment, the consensus among CAD vendors is that PDM/PLM offers the greatest prospect for future revenue growth, so look for the number of these offerings to rise.

About the Authors

Gregory Farnum is a Detroit-based journalist specializing in industrial and scientific issues. David Gehman has been writing about manufacturing and software for more than 20 years as both a journalist and a marketing communications specialist.

BY MICHAEL DEREN

'Tis the season!

Well, it's that time of year again. The holiday season is in full swing. One's thoughts turn to spending time with family and friends and exchanging gifts. Perhaps now is the time to think about giving to others as well.

I'm not talking about donating to well-known charities, such as United Way of America, The Salvation Army and the American Red Cross. Don't get me wrong, these are worthwhile causes, to be sure, and deserve our donations. I'm talking about other types of organizations that can use our help. They need donations other than food or money. A search on the Internet locates many organizations that accept computers, vehicles, machinery and even time.

There are scores of organizations that can use older, yet still working, computers. Many companies and individuals upgrade their computers regularly—perhaps, as frequently as every 2 or 3 years. These computers work quite well; they are just older technology. Meanwhile, they are ideal for training purposes. They can help people learn computer basics, such as word processing, creating spreadsheets and desktop publishing. Learning CAD/CAM is even possible with these older computers.

The computers just need to be newer units in working order—not your old IBM AT or one with a Pentium I system. One Web site, Santa Barbara (Calif.) Computers for Families (www.sbcff.org) lists fairly typical donation requirements, such as computers with Pentium II or higher processing capabilities, problem-free monitors with the Super Video Graphics Array display mode, and functioning power cords, keyboards and mouses. Computers for Families places these frequently donated computers in homes of children who cannot afford a computer.

Vehicular donations are also increasingly popular. There are many vo-tech schools that accept automobiles with engine or drivetrain problems or that are in need of body repair. These vehicles provide excellent hands-on training for students in auto-repair programs. Once these vehicles are repaired, they are typically auctioned off or otherwise sold by the school to provide additional funding. In many cases, the school picks up the vehicle. Boats are increasingly being donated as well.

If you are knowledgeable about turning or milling, volunteer some time to help students learn the trade.

One charitable organization that accepts vehicles is Volunteers of America, which has outreach programs throughout the U.S. The programs are created and managed locally. Each office determines the need of a particular community, such as youth and elderly services, and then designs and operates services to meet these needs. Donation requirements are simple: 1990 or newer cars, motorcycles or trucks; certain older-model cars; and powerboats, sailboats, campers and machinery.

Perhaps your company has some older lathes or mills sitting idle that run well but are crowding the shop. There are schools that can use these machines.

I often read and talk about the lack of trained personnel in the manufacturing industry. You can help remedy the situation by donating equipment.

Many small, little-known trade schools exist in the U.S. They accept donations of used machine tools, both large and small. The donated equipment, which only needs to be in reasonably good condition, is usually refurbished in-house for use in the school.

As an added incentive, donations can be written off your taxes. Touch base with the organization and your accountant to see about a possible deduction. In many cases, the tax deduction could be more valuable than selling or scrapping the item(s).

Last, but not least, is your time. If you have expertise in computers and software, many organizations can use that knowledge to help train students. The same goes for industrial equipment. If you are knowledgeable about turning or milling, volunteer some time to help students learn the trade.

The holidays tend to bring out the best in people. But don't just think about it during the holidays. Any time during the year is an appropriate time to donate. △

About the Author

Mike Deren is a CNC applications engineer and a regular CTE contributor. He can be e-mailed at mderen@prexar.com.