OCTOBER 2004 / VOLUME 56 / NUMBER 10

BY KEVIN COLE, ASSOCIATE EDITOR

CUTTING AT LIGHT SPEED

Lasers continue to make inroads into machine shops.

Lasers have evolved into powerful machines. Some feature 6,000w resonators, making them potent enough to cut steel more than 1" thick.

Additionally, because of advanced software and controls, the accuracy of lasers continues to improve. The newest models cut fine geometries and angles in steel, stainless steel and aluminum at high speeds.

Furthermore, the advent of rotary-chuck lasers with 3-D cutting torches allows tube, pipe and structural shapes that once could only be cut by conventional machines to be laser-cut (Figure 1). And, for a growing number of applications, laser processing has proven more efficient than conventional methods.

These developments don't mean machining centers, lathes and other metal-cutting mainstays are in danger of being replaced by lasers. Manufacturers are already able to cut thick materials with high accuracy on conventional machines. What would entice them to invest in a laser? Two things: saving time and saving money.

A Better Way

According to Larry Peake, group marketing manager for Strippit/LVD, a laser manufacturer based in Akron, N.Y., cutting speeds attainable by lasers cutting 2-D, 3-D and tubular parts (Figure 2) depend largely on the size of the laser's resonator, the type of material being cut and the thickness of the material. Some laser manufacturers boast cutting speeds of over 10,000 ipm on thin sheet metal, although, as Peake pointed out, typical speeds on thicker materials fall between 300 and 400 ipm.

In addition to the high speeds achievable with laser cutting, setup time can

Figure 1: Tubular and structural shapes that have historically been machined can now be cut on rotary-chuck lasers with 3-D cutting torches.

Lasers take on precision micromachining

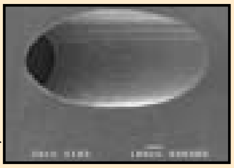
BY ANDREW WEBB

Lasers have been used to cut and mark metal for some time. But it has only been in recent years that they have been used for precision micromachining.

The reason is because producing extremely small part features is, in certain cases, beyond the capabilities of conventional machining—even electrical discharge machining. This forces engineers and researchers to seek alternative methods.

Modern lasers are compact, highly reliable and can produce micron-scale features. High-repetition-rate lasers, running in the 10kHz to 50kHz range and at nanosecond-pulse rates, can ablate many types of metals while meeting extremely accurate tolerances. Additionally, these lasers minimize the development of heat-affected zones, burrs and recast material.

Both copper-vapor lasers (CVLs) and diode-pumped solid-state (DPSS) lasers are well-suited to precision micromachining. The former is a gas laser with a fundamental green wavelength of 511nm and yellow wavelength of 578nm. Commercial applications performed by CVLs include the manufacture of fuel-injector nozzles and medical components.

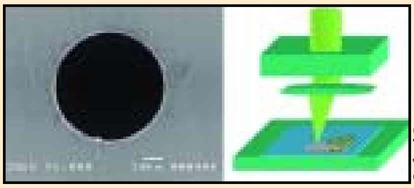


Oxford Lasers

The entrance of an angled hole laser-drilled in stainless steel. Because of the shallow angle, such a hole couldn't be produced by conventional cutting methods.

The DPSS laser incorporates crystals, in the form of rods, that are pumped by arrays of high-power laser diodes. Emission typically is at 1,064nm; this can be doubled to 532nm green to allow machining of metals. DPSS lasers are used to manufacture medical components, too, as well as parts such as cooling plates for fuel cells.

Both lasers can produce holes with diameters smaller than 250µm in materials up to 1.5mm thick.



Oxford Lasers

Trepanning holes with a laser provides greater machining flexibility than percussion drilling.

Percussion drilling is the simplest way to produce a hole with a laser. The technique involves focusing the laser beam directly at the workpiece. The beam's size and shape determine hole quality. This technique is ideal for machining extremely small holes quickly.

Trepanning is another technique, wherein the focus of the beam is rotated off-center via a dedicated optical device. This effectively trepans, or "polishes out," a percussion-drilled hole to a larger diameter. Compared to percussion drilling, trepanning offers improved hole roundness, higher repeatability and greater machining flexibility. A trepanned hole's diameter can be controlled as a CNC stage—and even be adjusted on the fly.

For milling and cutting applications, either the workpiece is moved in precision CNC stages or galvo-scanning mirrors deflect the beam to the fixed workpiece. Stages offer higher accuracy, but the galvo-scanning technique is faster, allowing high-volume hole drilling and parts marking. Combining either approach with an up-and-down axis makes 3-D manipulation possible.

About the Author

Andrew Webb is vice president of Oxford Lasers Inc., Industrial Division, Littleton, Mass. For additional information on the company's products and services, call (978) 742-9000 or visit www. oxfordlasers.com.

be reduced when moving from machining centers to lasers.

"The setup on a machining center and the fixturing and jig costs are largely eliminated by laser use," said Peake. "You just lay parts on a table, input coordinates and cut them."

Another timesavings the laser offers involves part changes, said Ancel Thompson, head of Amada America Inc.'s laser division, Buena Park, Calif. "For instance, if you are cutting a gear mechanism that is about 2" in diameter and the engineers make a design change to make it smaller and lighter weight, so now it is 1¾", you don't have to purchase more tooling or do additional machining to the inventory you have," said Thompson. "You just reprogram the part into the machine to cut it out of a smaller section of the sheet. You don't have to go through different setups to change mills or change tools to produce that particular part."

But the potential savings don't end there. According to Glenn Berkhahn, senior vice president of Mazak Laser Corp., Schaumburg, Ill., material-utilization rates for lasers are considerably higher than for machining centers. In a test comparison performed by the company, six parts were cut on both a machining center and a laser. The machining center utilized 53 percent of two 4'×8' steel plates, whereas the laser used 71 percent of a single 4'×8' steel plate for the same parts. Berkhahn credited the material savings to virtually clampless operation and a narrow kerf.

Moreover, he added, the laser needs no tools to be sharpened, maintained, purchased or replaced when broken. No coolants are used, eliminating that cost and costs associated with filtering and disposal. (Lasers, however, do occasionally require new nozzles, which are relatively inexpensive.) Plus, 3-D lasers can perform several operations at once, so there is no waiting time between operations.

Thompson pointed out that with laser cutting, there are no chips to clean up or dispose of, making the scrap more manageable.

Peake said, "Some lasers, depending

on the size of the resonator, operate at $10 or $12 per hour. Machining systems can be much more expensive."

Limiting Factors

Lasers may save time and money in some cases, but there are areas in which they just can't compete with conventional cutting equipment.

Peake said that lasers work best on flat parts and are limited in the tolerances they can achieve. He said that, depending on the material being cut, its thickness and the speeds it is being cut at, most lasers can achieve tolerances of at least ±0.002". Of course, many machining applications require much tighter tolerances.

"Machining can hold tighter tolerances because lasers are a thermal process," explained Thompson. "As you put heat into the material it expands. That makes it a little difficult for lasers to hold as tight of tolerances as milling. But what you don't have to worry about with the laser is [compensating] for a slightly worn tool, as with milling. You are going to have better repeatability with a laser."

Peake also explained that while lasers provide a fairly fine finish, they are incapable of achieving the kinds of finishes possible with conventional machines.

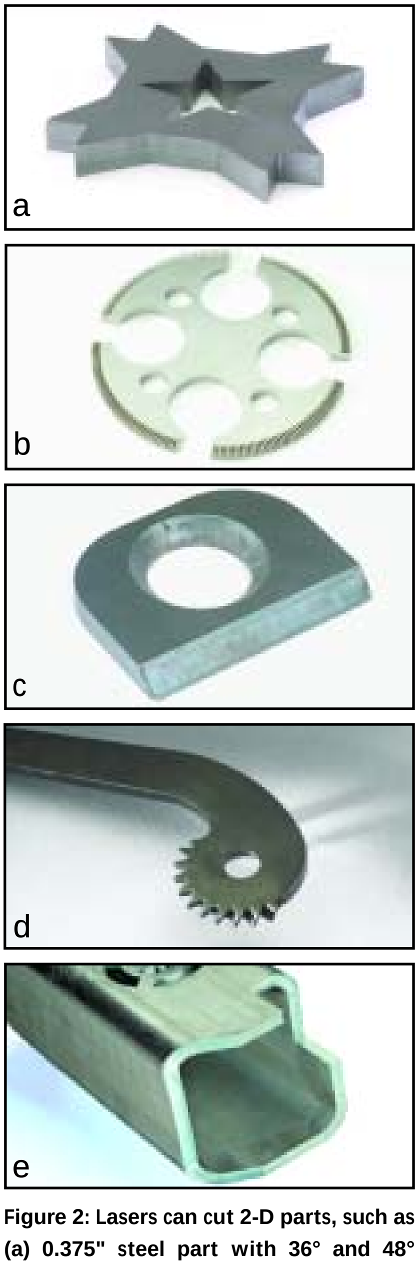
"Lasers will give a rougher finish than machining, which can give you a very high polish—like an 8 rms," agreed Thompson. "A laser-cut edge is considerably rougher, maybe a 64 rms—or maybe even as rough as a 128 rms."

Another obvious disadvantage of a laser is the high initial investment compared to, say, a machining center. Top-end machining centers cost $200,000 to $400,000. A laser, depending on its size and power, can cost as much as $1 million. However, if thrown into high use, this capital expenditure may provide a return on investment in less than 2 years.

"While the future of lasers may be bright, they are still inappropriate for processing parts much over 1" thick or requiring blind holes," said Berkhahn. "However, in so many applications … lasers can free up machining centers for the jobs they do better."

The Proof Is In the Production

"There is a subtle move by some companies [to laser-cut parts]," said Peake, who also pointed out that most of the examples he has seen were companies that had both fabrication and machine shops. "If you look at companies that work in thicker materials, such as John Deere or Caterpillar, they have moved certain applications to laser cutting. Weld joints and clearance holes are good examples."



Mazak Laser

Figure 2: Lasers can cut 2-D parts, such as (a) 0.375" steel part with 36° and 48° angles and (b) ¼"-thick stainless steel precision sprocket; 3-D parts, such as (c) ¾"-thick steel beveled and chamfered part and (d) ¼"-thick steel part with laser-hardened and chamfered teeth; and rotary parts, such as (e) 3" steel tube with ¼" wall thickness.

He added that he thinks there is a trend among companies machining tubular products, particularly in the construction-equipment business, to gravitate toward lasers, which can cut tube with wall thicknesses of ½" and diameters up to 20".

One company that cuts tubular products and found savings by incorporating a laser into its cutting operations is Production Cutting Services Inc., East Moline, Ill.

Bill Duy, owner and president of PCS, explained problems he encountered when making a part for a piece of farm equipment out of a 4"×4", ½"-thick, rectangular tube before using a 3-D rotary laser (Figure 3).

"It was a very complicated part to process manually," he said. "First, we'd cut it to length. Then we'd bring the pieces to the machining center, where there were two vises. Each vise held the part for two positions, and the machine was programmed to drill holes in a side for each position."

After each side was done, the operator had to stop and turn the tube to the next side. So, he had four setups per piece. Once all the holes were drilled, the operator deburred the inside edges of the holes with a hand tool. Duy said, "Overall, it was time-consuming and labor-intensive."

The following companies contributed to this report:

Amada America Inc.
(714) 739-2111
www.amada.com

Baker Oil Tools
(713) 466-1322
www.bakerhughes.com/bot/

Mazak Laser Corp.
(847) 252-4500
www.mazaklaser.com

Production Cutting Services Inc.
(309) 755-4601

Strippit/LVD
(800) 828-1527
www.lvdgroup.com

The process was problematic for a number of reasons. “The operator had to pay close attention to make sure he was rotating the part the right way,” he explained. “If the holes ended up on the wrong side, the part wouldn’t be any good. The machining process also caused problems. If the operator clamped the part into the vise and debris from the previous process was caught in between the part and vise, this would skew the dimensions. So, the operator had to blow all the chips off the work area each time the tube was rotated, adding more delays.”

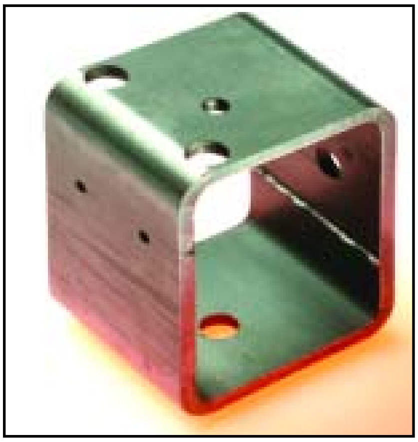
Duy also explained that drilling can degrade accuracy and lead to burr formation, because of vibrations caused by contact with the part. This forced PCS to check every part. However, that changed when the company started using a rotary laser.

“We put a 10' tube into the rotary chuck, and it does all the work,” said Duy. “The laser is programmed to cut the right holes in the right face. The rotary chuck automatically rotates the part, so there’s no more manual turning. And, with our laser, we don’t have to be concerned with debris or grinding [away] burrs.”

He said that after the holes are drilled, the laser cuts the part off and starts the next part. This reduces the number of operations from three to one, eliminates three of four setups and, combined with allowing 10 parts per chucking, lowers cycle time 40 percent.

“Since we started using the rotary laser, we’ve dramatically reduced lead times and labor costs, and we haven’t made a single bad part—not one,” said Duy. “Operator error has been eliminated and hole placement has been extremely accurate. There are no vibrations with a laser, so that’s another reason the quality has been so much more consistent.”

Baker Oil Tools, Houston, a manufacturer and designer of tools used for the exploration and production of oil and gas, also saves time and money by producing parts with a laser.



Mazak Laser

Figure 3: This part made out of a 4"x4", ½"-thick, rectangular tube is laser-cut, rather than machined.

Eric Blanton, manufacturing engineer with Baker, discussed two parts made by the company: One is made from a ⅜"-thick, 10"-dia. 4140 carbon steel tube and the other is from 2'×2' cylindrical bar stock of the same carbon steel (Figure 4).

The first part is cut to length on a saw and then threaded on a lathe. The laser cuts the 2.5"×2.5" windows and the milling teeth at the top. “Each window has a slight bevel, so we use the 6-axis 3-D features as well as the rotary capabilities of our laser,” Blanton said. He explained that milling the part took two setups, one to mill the windows and one for the teeth, which took about 1½ hours each. Milling the part took between 45 and 60 minutes. “We cut this part on the laser in less than 5 minutes,” he said.

The second part, which is 1" tall and has a 0.25" diameter, is made by drilling the bar and then turning it. Then Baker laser-cuts the 84 square windows, which are each 0.060"× 0.060". The company tried to use a very small endmill and electrical discharge machining to cut the windows. “They all held the tolerance—the quality was fine,” Blanton explained. “But compared to the laser, the mill and EDM were a lot slower. We found that by using the laser, the actual run time for this part was reduced by 90 to 95 percent.”

Mazak Laser

Mazak Laser

Figure 4: Most of the features on these parts were cut with a rotary laser, one (a) from a ⅜"-thick, 10"-dia. 4140 carbon steel tube and the other (b) from 2'×2' cylindrical bar stock of the same carbon steel. Unlike previously milled versions, these parts can be made on one machine. Switching from one part to the other can be accomplished in less than 5 minutes.

Blanton also said milling the part required specialized fixtures holding both ends to make sure it didn’t move, which added to the setup time. He said that with the laser no complex fixturing is needed because there is no force being placed on the part. Also, when milling, the tooling had to be checked for wear after every few parts, which added to cycle time.

Baker and other manufacturers aren’t getting rid of their machining centers yet. But they are definitely putting more thought into what parts should be cut on which machine since they’ve invested in laser technology.