

Increased cutting speeds and more precise cutting are now possible, driven by higher cutting pressure and higher powered software. It's widely accepted that in terms of raw metalcutting speed, waterjets rarely beat plasma and other thermal cutting methods. Rather, the growing popularity of waterjet cutting stems from its other qualities. "The main competitive edge for waterjets over all thermal methods is the ability to produce precision parts with very few, if any, secondary operations," notes John Olsen, vice-president, operations, Omax Corp. (Kent, WA).

Given the clean, accurate parts it creates, abrasive waterjet cutting's overall cost picture is attractive in many applications. For example, holes created with abrasive waterjets can be directly tapped or reamed, requiring no intermediate slag-cleaning operations, adds Olsen. Thus, more manufacturers, especially smaller shops, are taking advantage of waterjet cutting and the accompanying system improvements being made.

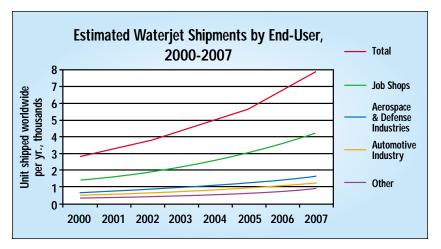
In fact, job shops are making the majority of all new waterjet purchases (see graph). And across the board, world waterjet sales are projected as growing at 12 to 16% per year over the period 1997-2007, according to market research firm Frost & Sullivan (San Antonio, TX).

The growth appears to be technology-driven. Ever since the technological "leap" with the invention of abrasive cutting in 1979, allowing waterjets to cut thick metals, OEMs have been striving to overcome waterjet's shortcomings, says Chip Burnham, VP of Flow Intl. Corp. (Kent, WA). Improvements in process control, automation, and cutting speed have been the drivers, starting in the 1990s and continuing today.

# Are "Hyper" Pressures Cost-Effective?

"The most common request is to cut the product faster," says Burn-

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ham. "Faster cutting typically means cheaper cutting. It also means that a given machine can produce more work and more money."

Cutting speed is most easily increased by using higher water pressures. Last year, Flow announced its "HyperPressure" waterjet that cuts with 87,000 psi (600 MPa), which is about 50% higher than standard "ultra-pressure" cutting (see Forming & Fabricating, Nov. 2002, p. 24). The benefits of its 40% faster cutting speeds are obvious, but one question remains: Given the greater component fatigue from the higher pressures, what's 87k's real cost per foot cut?

Burnham says basic demonstrations show that cutting speed increases linearly with pressure. At the same time, abrasive consumption—a major cost burden—decreases, and kerf width is reduced by 25%, saving raw material. Thus, "you'll also find the cost per inch cut dropping as pressure increases."

This means economical cutting is possible at 87k. Despite the higher perceived maintenance costs of the pump and components, the higherpressure process reportedly cuts 1/4" (6.4 mm) stainless steel about 40% cheaper than 55,000-psi (380-MPa) cutting (see table). The 50% reduction in garnet abrasive consumption is key to the cost advantage, since abrasive is about two-thirds of total operating costs at standard pressures.

The system's cost-effective pump performance at 87k is the result of pump technology originally developed for high-pressure food preservation. Unlike standard waterjet pumps, food-processing-style pumps operate with a non-continuous duty cycle, saving wear and tear on the pump cylinders and seals.

The company's betting that 87k cutting will become standard in the industry. "Just as the normal operating pressure of a waterjet system rose from the 30,000-psi (207-MPa) range to 60,000-psi (414-MPa) range over the past 20 years, so we'll see Hyper-Pressure systems as common within the very near future," says Burnham.

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	55,000 psi pure waterjet	55,000 psi with garnet abrasive	87,000 psi pure waterjet	87,000 psi with garnet abrasive	Notes
General per-hour operating cost factor, including maintenance costs (55,000 psi w/ abrasive = 1) Speed to cut 1/4" stainless (ipm)	0.25	1	0.35	0.8	Materials cuttable by abrasive and non-abrasive methods are not the same.
Abrasive use factor, per inch cut	n/a	10	n/a	14	For "high-quality" cutting. (87,000 psi pure waterjet limited to slitting metals < 1/16" thick.)
(55,000 psi = 1) Operating cost factor, per inch cut, including maintenance costs	n/a	1	n/a	0.5	7 10 unoky
(55,000 psi = 1)	n/a	1	n/a	0.58	

"There is, of course, a practical limit to how high a waterjet system operating pressure can reach, but that limit is far from being reached."

#### **FASTER MACHINE MOVEMENTS**

Higher pressures are of interest to other waterjet OEMs, says Joe Blackmon of ESAB Cutting Systems (Florence, SC). ESAB's waterjet systems incorporate intensifier pumps and cutting heads from Ingersoll-Rand (Baxter Springs, KS), which Blackmon says is also looking at cutting pressures above 55,000 psi (380 MPa).

But also important for reducing operational costs and machine cycle times are advancements in automation and motion control. Faster movement of the waterjet cutting head from one completed cut to the pierce point of the next part can save precious seconds.

Blackmon says a net increase in travel speed can result from effective control of cutting-nozzle height. "Historically, and on some lowerend equipment, control of nozzle-toworkpiece height was maintained manually." However, ESAB's "height control" technology automatically finds the proper height to start the

### **Small Solution Addresses Abrasive Recycling for Job Shops**

Systems for recycling waterjet abrasive media have steadily been gaining acceptance, says Richard Ward, CEO of WardJet Inc. (Kent, OH). With garnet abrasive contributing to most of a waterjet's operating costs, there's a natural motivation for wanting to re-use it.

Over the last four years since the company started supplying abrasive recycling systems, Ward has been listening to what prospective customers are calling for: more compact, easier-to-use systems. Thus, the company has developed the "Ward 2," a lower-capacity model incorporating many of the components and principles of the first system.

The larger "Ward 1" was aimed at users who typically operate multiple heads and run long hours every day. About 90% of the units have been retrofits for existing waterjet systems for companies, such as specialty distributor Castle Metals (Franklin Park, IL), that operate several units. However, most waterjet shops are smaller businesses often employing less than ten people,

and these shops use less abrasive per month.

Thus, everything is reduced in the Ward 2 design. Its drying capacity per hour [50 lb (23 kg)] and maximum drying capacity per



month [20,000 lb (9000 kg)] are about one-fifth as great as Ward 1. Plus, its  $42 \times 42$ " (1.1  $\times$  1.1 m) footprint takes up half the area, and its power requirements are 110 V rather than 480 V.

Otherwise, the smaller unit incorporates many components and principles of Ward 1. Components include a washing and separating plant, dryer, a screen to sift out oversize particles, a splitter that segregates the dry abrasive into two grades, a dry storage hopper, a dust and steam collector, a waste drum to collect undersize waste sludge, and a programmable controller.

The smaller system reportedly addresses the needs of companies using about 2200 lb (1000 kg) of abrasive per month, rather than the 5000 lb (2250 kg) per month required to justify the larger unit. Even with the lower capacity, Ward claims a waterjet cutting with one head, one shift per day, could save enough abrasive to make the payments on a \$200,000 waterjet system "and possibly have some cash left over."

For more information about abrasive recycling, circle the appropriate number at the end of the main article.

initial cut, then maintains the right distance from the plate for all cuts, through continuous or periodic height sampling.

Once a cut is finished, the cutting tool is raised to a safe travel distance from the workpiece to travel to the next pierce point. When it arrives, the height control finds the proper pierce height for the next cut, without operator intervention.

Height control can significantly reduce cutting-head movement time. "In the past, the machine's travel speed was mainly around 300 ipm (7.6 m/min), but with height control we get the traverse speed up to around 1100 to 1500 ipm (28 to 38 m/min)," says Blackmon.

There has also been work towards increasing maximum travel speeds with new motion drivers. Flow Intl. has been looking into linear drives rather than ball-screw or rack-and-pinion systems for moving the cutting head. Early R&D shows that lin-

ear drives' magnet-based movements produce higher accelerations and speeds over 5000 ipm (127 m/min), across a  $6' \times 10'$  ( $2 \times 3$  m) envelope.

#### **SETUP SAVINGS**

Waterjet cycle time is being cut in more subtle ways. For example, to trim setup time, ESAB offers a "vision plate location and orientation system" that adjusts the cutting program to the raw plate's actual position, even if it's skewed just one-half degree off perfect placement.

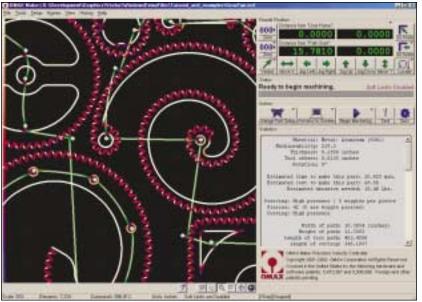
First, the system uses a camera to find the plate's edges, explains Blackmon. "If the plate is not exactly straight to the rail, then instead of the operator having to re-set the plate exactly square, the alignment system goes around and finds reference marks on the plate and automatically adjusts for the plate's skew."

The cutting head can then make cuts that have the proper orientation to the plate edges. The opportunities for setup time savings are obvious: for example, operators don't need to wrestle with a  $10' \times 20'$  ( $3 \times 6$  m) plate weighing several thousands of pounds to make it square.

## WATERJET'S UNIQUE CONTROL CHALLENGE

Notable waterjetting improvements in recent years have come from more accurate, computer-enhanced controls. Programs and hardware have been specifically designed to compensate for the waterjet's characteristics during the cutting of complicated nests of parts. Potential cutting speed is limited by the jet's "stream lag" effect, which causes taper and dimensional variations on the cut edge, especially at inside corners and around arcs.

"Modeling and understanding jet behavior is increasing the possible precision of the process," says Omax's John Olsen. "A steady improvement of this understanding, rather than a sudden breakthrough, is the main



The screen-shot shows the programming in Omax's Intelli-Max software for waterjet cutting quarter-inch-thick aluminum gears. The software calculates the optimum cut path and speed, and estimates the amount of abrasive consumed.

technology driver. It permits new machines that eliminate not only effects of jet lag, but effects of the natural jet taper. Implementation of this knowledge requires the computing power of modern PCs and the efficient programming languages available for them." CNC-based controllers offered with some systems have never adequately been able to handle waterjet phenomena for accurate cutting, adds Glenn Binder of cutting software-specialist SigmaTek Corp. (Cincinnati). "These CNC systems reside on the machine control and don't work very well, especially for large nests."

So the push has been for specialized waterjet control systems that adjust for lag and other peculiarities of waterjet cutting. They allow the cutting head to maintain higher average speeds when cutting complicated parts. Flow's Dynamic Waterjet hardware/software-based system has been one advancement; the system uses angled 3D cutting to create a non-tapered edge on the workpiece at high speeds (see *Forming & Fabricating*, March 2002, p. 40).

Flow's Mike Ruppenthal says the system is now available with its lower-priced, best-selling Integrated Flying Bridge cutting system. "We've just halved the entry cost for a customer wishing to own a Dynamic Waterjet."

#### SOFTWARE-BASED CONTROL

Other companies address the lag issue with totally software-based approaches to control. For example, SigmaTek's SigmaNest software allows off-line programming for creating the best nesting and fastest cutting. Glenn Binder says the PC/Windows-based software is designed to automatically control the waterjet's shape distortion, lag, and corner ramping. The software reportedly has been adopted by OEMs for new systems and end-users making system upgrades.

Omax has recently updated its own control software that's said to maximize cutting speed while reducing taper. The "Intelli-Max" software suite is a user-friendly update of the company's original 1993 controller, says Olsen. "The original controller was DOS-based, subject to memory limitations, and was without multitasking. The new control uses Windows 2000 and compiles a cutting path in about 10% of the time required by the old version."

He says all PC functions available to desktop computing are available with the software, including networking, Internet-integrated troubleshooting, remote machine monitoring, and video training for operators. "Increased computing power allows even better prediction and management of jet behavior to produce accurate parts."

A number of enhancements are attached to the software suite's control program (simply called "Make"). A nesting component sets the nest array and tool path automatically, setting part rotation and spacing to optimize material usage for both single- and multi-nozzle waterjet cutting. A piercing component uses a model to predict the best distance and speed for part and material, automatically growing or shrinking the lead-in at the pierce point to the ideal distance, without interfering with other features in the part.

The "Intelli-Taper" component allows the user to specify certain regions of the part as "minimum taper," allowing increased cutting speeds around those sections. Finally, a "cornering" feature selects an appropriate computer model and cutting speed depending on whether the jet is entering or exiting a corner, and whether it's an inside or outside corner.

# **WANT**More Info?

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The program can take advantage of certain corner layouts to maximize overall speeds, "instead of slowing down for corners to compensate for jet behaviors, such as jet lag and kick-back," says Olsen. In other words, the software determines when part configuration and tolerance don't require the head to slow at a corner.

"Intelli-Max software has caused us to change our design recommendations for parts. Previously, parts with round external corners were quicker to make than with sharp corners. Now, the reverse is true." Consequently, he says the greatest speed gains with the software occur for parts thicker than 1/4" (6.4 mm) that have multiple, sharp, external corners.