OCTOBER 2007 / VOLUME 59 / NUMBER 10

cover story

BY ALAN RICHTER, EDITOR


Jet Edge

Pump It Up

As technology is introduced to increase the waterjet's pressure rating—up to 87,000 psi—some industry experts question its advantages while others see benefits.

How big is big? How fast is fast? How high is high?

In abrasive waterjetting, the pressure rating that defines ultrahigh-pressure (UHP) cutting is a moving target. According to Brad Schwartz, West Coast regional sales manager for Jet Edge, St. Michael, Minn., the top pressure rating in the mid-1980s was 36,000 psi and is now 60,000 psi for Jet Edge. He indicated that few in the industry are cutting using waterjets with less than 55,000 psi, which is the generally accepted starting point for UHP.

Last year, Flow International Corp., Kent, Wash., introduced an 87,000-psi HyperPressure waterjet. Chris Maier, Flow's product manager for shape cutting, said the 45 percent increase in pressure from a 60,000-psi UHP system reduces workpiece taper by up to 0.001", uses 30 to 50 percent less abrasive and cuts 30 to 50 percent faster. "That translates into lower part cost," he said. The 87,000-psi waterjet cuts part cost by 20 to 30 percent, according to Flow.

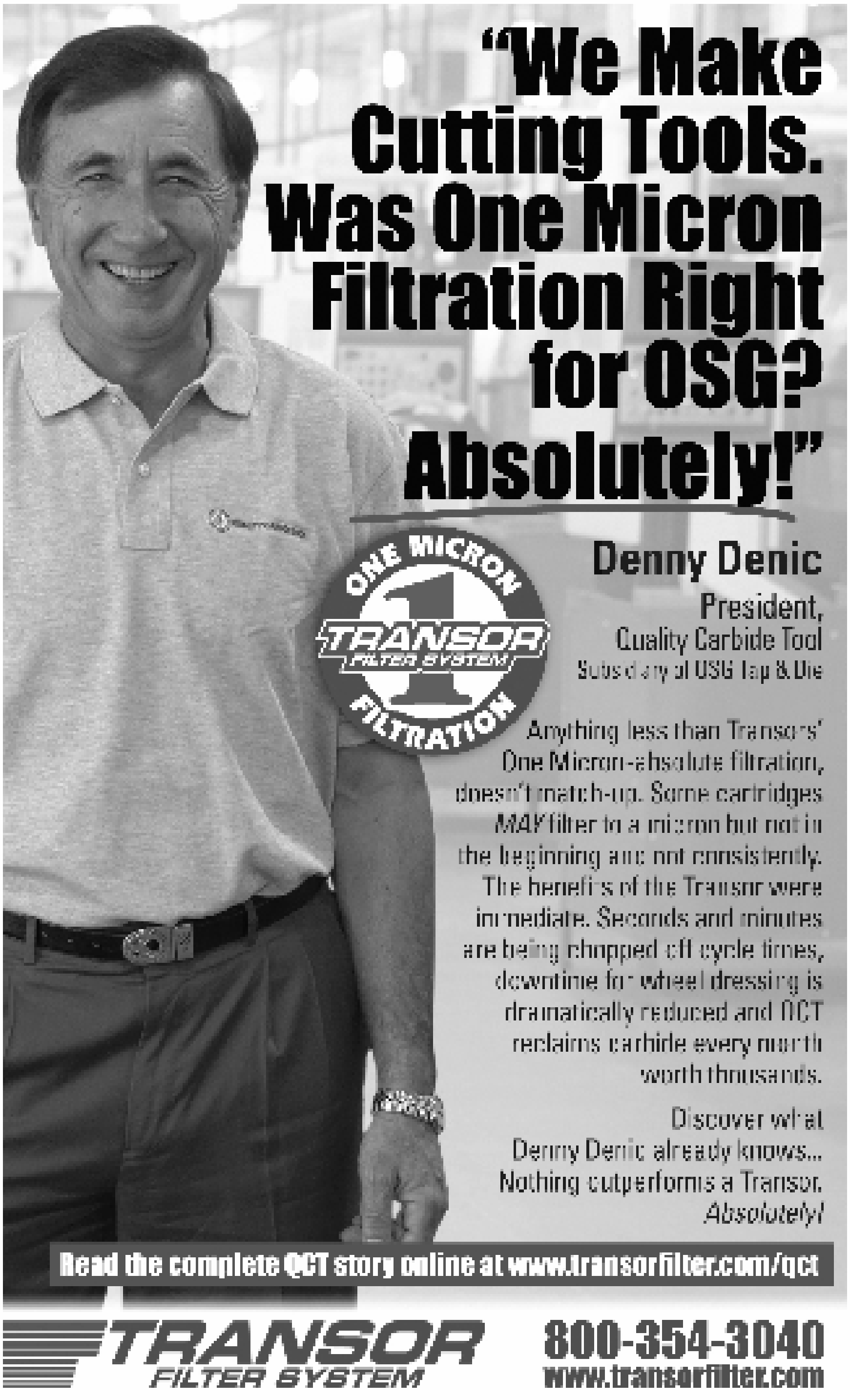
When looking into an UHP waterjet system, a shop should consider its facility's layout, including utilities, electrical voltage and water drainage capabilities, noted Bob Pedrazas, marketing manager for KMT Waterjet Systems Inc., Baxter Springs, Kan. "A water sample should also be conducted to determine if special water filtration is needed to ensure longer component life," he said.

Pressure Production

The waterjet system's pump creates the pressure, and most UHP systems use an intensifier pump. A white paper from Flow about its HyperPressure waterjet technology explained the basic mechanics of intensifier pumps. Two fluid circuits exist in a typical intensifier pump: the hydraulic circuit (using oil) and the water circuit. In the hydraulic circuit of a 60,000-psi intensifier pump, hydraulic oil is pressurized to 3,000 psi. This oil passes through valves that create the stroking action of the intensifier by sending hydraulic oil to one side or the other of the biscuit/plunger assembly (Figure 1). The small arrows denote 3,000 psi of oil pressure pushing against the biscuit. The biscuit is attached to a plunger that, in turn, pushes against low-pressure water in the water circuit, which is depicted with the large arrow.

In the water circuit, low-pressure water is pressurized up to 60,000 psi through use of an intensification ratio, which is the relationship between the biscuit's surface area and the plunger's surface area, the paper continued. In this example, the biscuit has 20 times more surface area than the plunger. Therefore, the intensification ratio is 20:1. The 3,000-psi hydraulic oil pressure against the biscuit is intensified 20 times when the smaller plunger face pushes against water, yielding 60,000-psi water pressure.

The HyperPressure's pump uses the same 3,000-psi oil pressure but employs a 33:1 intensification ratio to yield 100,000-psi water pressure. Flow stated that the operating pressure is limited to 87,000 psi for improved



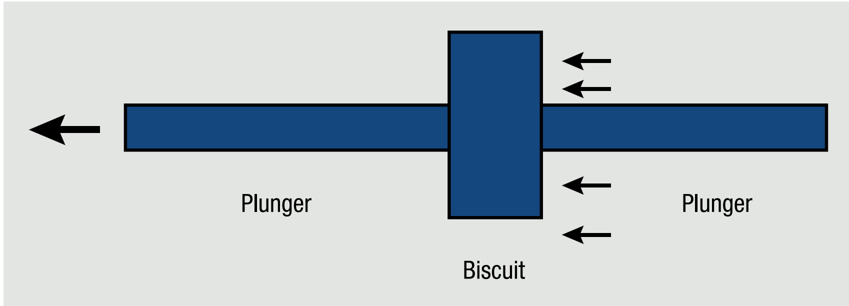
KMT says the benefits of its 60,000-psi pumps, such as the Streamline SL-V 200R Plus, include higher throughput, less dust accumulation, taper reduction and a reduction in abrasive costs to as low as $6 per hour.

component life.

Schwartz noted that variable-displacement, axial piston, hydraulic pumps supply oil to an intensifier pump at about 3,000 psi. The intensification ratio is 20:1, so the resulting high-pressure water that's developed is sent directly to an attenuator, a large stainless steel cylinder or accumulator, which dampens the pressure cycles and supplies an even water flow and pressure to the cutting head, he added.

In contrast, lower-pressure waterjets use positive-displacement or crank pumps. "Those types of pumps are always pumping water when they're on," Schwartz said. "With an intensifier pump, when the jet turns off, the intensifier stops stroking."

Direct-drive pumps are another type for UHP systems, which OMAX Corp., Kent, Wash., makes for its waterjet machines. John Olsen, Ph.D., the company's vice president of operations, explained that a direct-drive pump has a closed chamber full of water and a rod is pushed into it to expel the water. "The pumping principle is exactly the same as the intensifier," he said. "The difference is what you use to do the pushing of the rod. An intensifier pump uses a hydraulic piston to push the rod, and a direct-drive pump uses a crankshaft, much like an automobile crankshaft."



Flow

Figure 1: The small arrows denote 3,000 psi of oil pressure pushing against the biscuit. The biscuit is attached to a plunger that, in turn, pushes against low-pressure water in the water circuit, which is depicted with the large arrow.

According to Olsen, the advantages of a direct-drive pump include its quieter operation and 90 percent efficiency rating vs. 60 percent for intensifier pumps. "When you're running 50-hp motors, it's like a dollar an hour or more [of savings] in electric costs," he said. The increased efficiency also reduces water consumption. "The hydraulic-drive pumps dissipate the waste energy as heat and then you have to carry that heat away some way and the usual way to do it is with a heat exchanger," Olsen said. "First you pay for the electricity, and then you pay for the water to carry the waste electricity away."

Hyper or Hype?

The benefits of an 87,000-psi waterjet may seem compelling, but some in the industry question the need for and benefits of the higher-pressure technology. Olsen, who developed the intensifier technology for Flow, is one of them. "I built the first Flow units in my backyard—literally. It seems like just last year, but that was in 1971," he said, adding "In waterjet, not everything good comes from focusing only on pressure. Just as in driving a car, steering can become dominant over power, when moving—cutting—along a toolpath with any sort of complexity."

OMAX builds waterjet cutting machines with a peak pressure of 55,000 psi. According to Olsen, there is a reasonable performance improvement when cutting at 55,000 or 60,000 psi compared to 40,000 psi, for example, but going to a higher pressure doesn't improve it further. "At OMAX, we have taken parts cut at 87k and found that we cut the same parts faster at 55k with our system because of the steering control provided by our IntelliMax software," he said.

Olsen added that pressure can be important to overall cutting speed when cutting straight lines, "but if all you are after is increasing cutting speeds for straight lines, a saw is cheaper and faster. For us, the plateau was reached at about 55k to 60k, and that is why we don't focus on quoting straight-line cutting speeds."

Olsen said that above 60,000 psi, "you pass through a threshold where

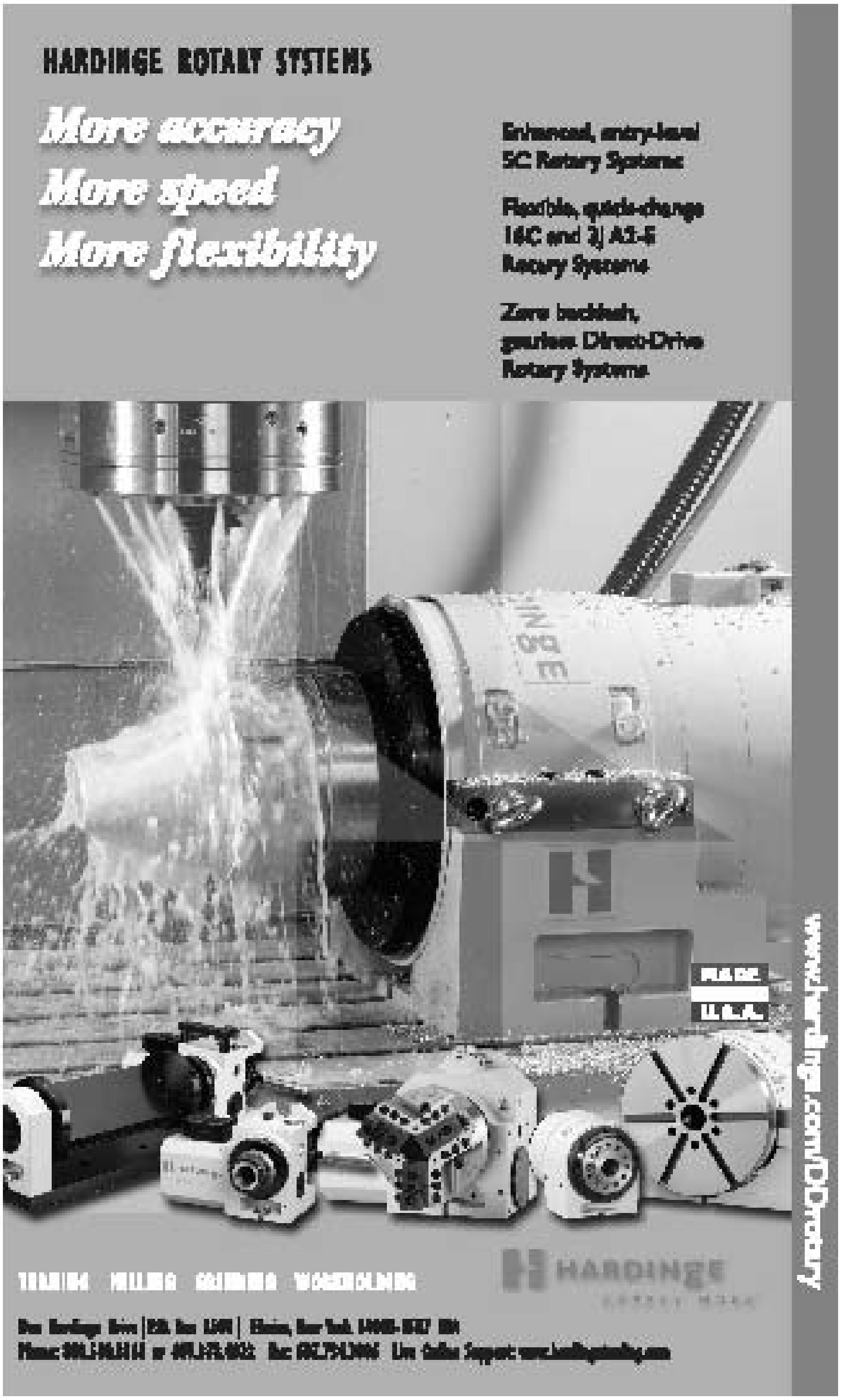
Recommended starting-point feed rates for a given workpiece material.

Material	Thickness (in.)	Separation cut (ipm)	Medium-quality cut (ipm)	High-quality cut (ipm)
Copper	0.5	18.7	7.6	4.8
	1.5	5.2	1.7	1.0
	3.0	2.3	0.7	0.4
304 stainless steel	0.5	13.0	5.2	3.3
	1.5	3.6	1.2	0.7
	3.0	1.6	0.5	0.3
Aluminum	0.5	40.2	16.3	10.2
	1.5	11.2	3.8	2.3
	3.0	5.0	1.5	0.9
Mild steel	0.5	14.4	5.8	3.7
	1.5	4.0	1.3	0.8
	3.0	1.8	0.5	0.3
Titanium	0.5	20.1	8.2	5.1
	1.5	5.6	1.9	1.1
	3.0	2.5	0.8	0.5
Granite	0.5	35.9	14.6	9.1
	1.5	10.0	3.4	2.0
	3.0	4.5	1.4	0.8
Inconel 718	0.5	11.5	4.7	2.9
	1.5	3.2	1.1	0.6
	3.0	1.4	0.4	0.3

Based on cutting using a 55,000-psi waterjet with 1.1 gpm of water, a 0.014" orifice, a 0.040" nozzle and 1.1 lbs./min. of 80-mesh abrasive. Source: Jet Edge

Flow

Flow's Integrated Flying Bridge 6012 waterjet cuts at up to 87,000 psi.



metal fatigue becomes the dominant failure mechanism." He noted that at 55,000 to 60,000 psi, high-pressure cylinders, for example, can be made to withstand millions of cycles and provide long service life. "When you climb above that, the cycle life begins dropping fairly dramatically, and you have much shorter finite life," Olsen said.

Higher pressure places increased stress on materials that can cause them to deform, wear prematurely or fail in an unpredictable manner. As a result, Flow reported that the design and function of many components of its 87,000-psi pump are different from the company's 60,000-psi pump. "It's a higher-pressure system, so anything that experiences that higher pressure has been redesigned for 87k," Flow's Maier said. Those components include dynamic and static seals, check valves, tubing and high- and low-pressure cylinders. "We're getting seal life equivalent to or greater than what we find with 60k technology," Maier added.

Will Witten, director of operations for The Peerless Group, Sidney, Ohio, can't compare the maintenance requirements for an 87,000-psi waterjet to a 60,000-psi one because Flow's HyperPressure is the company's first waterjet machine, but his experience with the equipment has been positive. "Since startup, it's been problem free," he said. "Part of Flow's 87k package is they provide first-year maintenance on the pump, but we haven't been in a spot where we've needed that yet."

Flow's Maier pointed out that although there's training specific to servicing an 87,000-psi intensifier pump, it's essentially the same as the training for 60,000-psi technology. "Anyone who can service a 60k intensifier is able to service an 87k intensifier," he said, adding that customers are able to service the higher-pressure pump in-house.

The Peerless Group recently added a second shift for the machine, so the waterjet runs about 100 hours per week. The shop cuts a variety of materials from ¹⁄₁₆" to 3½" thick, including

Shop grows with waterjet technology

Pegasus Northwest Inc., Kent, Wash., is a Boeing-certified abrasive waterjet cutting service company. Armed with two high-rail gantry waterjet systems from Jet Edge, Pegasus uses diamond orifices and the highest-grade garnet abrasive on the market for producing high-accuracy parts, said Ron Palstring, Pegasus' plant manager.

Pegasus Northwest got its start in 1970, cutting decorative panel blanks for Boeing aircraft with a shear and panel saw. This niche service was the heart of its business until 1997, when Boeing persuaded Pegasus to expand beyond blanks and produce final parts utilizing CNC programming.

After researching its options, Pegasus decided abrasive waterjet was the best method for cutting stacks of the phenolic resin panels, while providing the flexibility to produce other parts from virtually any material, Palstring recalled. "It's important we stack our material for efficiency," he said. "Other cutting methods prohibit stacking and cutting multiple layers deep."

Pegasus researched several waterjet systems before deciding on a 12'×14' high-rail gantry that could cut four sheets of material at once. The system is powered with a 50-hp intensifier pump and the gantry is equipped with a 6' spreader bar with two abrasive jet cutting heads and two pneumatic drill units. The company applies the drills to prepierce materials prone to delaminating.

Before long, Pegasus branched out beyond the aerospace market and began doing work for other industries. "Everyone around us found out about our waterjet, and they would drop off a P.O. and blank material at our door," Palstring said. "Today, 80 percent of our business is aerospace contractor work and 20 percent is miscellaneous."

In 2000, Pegasus needed a second waterjet system to keep up with demand. They purchased a custom-designed 12'×8' Jet Edge high-rail gantry with a 6' spreader bar, four cutting heads, one pneumatic drill and a 150-hp intensifier pump.

Since installing its waterjets, Pegasus has grown from three employees to 25 and has moved from an 8,000-sq.-ft. leased facility to a 25,000-sq.-ft. facility it owns. The company has eight waterjet operators and runs its systems 100 hours a week.

Palstring attributes his company's success to following detailed procedures. "Our niche is tight tolerance," Palstring said. "We hold ±0.005" on 1" titanium and aluminum parts for a couple of our customers. We maximize every inch of the table with sheets that are 12' long. Having an envelope that size saves time and materials, and we pass that savings on to customers."

Pegasus Northwest

A Pegasus waterjet cuts 6.5" forged titanium billets for Boeing, leaving 0.250" of excess material to be machined during finishing.

Some of Pegasus' more challenging projects include cutting 26,000 9"-thick titanium billets for the Boeing 787 and cutting sphere sink bowls for Pegasus' sister company, Lumicor, which manufactures architectural panels, sinks and countertops from resin. To cut the sink bowls, Pegasus tilts the waterjet head and spins the sink bowl blank on tooling it made in-house.

Palstring said the high-rail gantries are accessible for loading and unloading and found the pumps are reliable. "We're able to access the table from 360°," he said. "It is very easy to load."

He also found the pumps are easy to maintain. "Replacing the seals takes 30 minutes max," Palstring said.

mild steel, stainless steel, aluminum and Lexan, a polycarbonate resin thermoplastic from General Electric Co. that's intended to replace glass.

After looking for a waterjet on and off for a couple years, Witten noted that the company decided to buy the 87,000-psi unit shortly after it was commercially available. His waterjet has a 100-hp motor, which has two intensifiers compared to one for the 50-hp version. "We wanted to buy what was current or coming rather than what was past," he said.

The machine can be fitted with multiple heads, but Witten chose a one-head machine because the majority of the shop's jobs are for single parts.

As part of the justification process, The Peerless Group conducted computer simulated races between 87,000- and 60,000-psi waterjets. "The simulation showed we were going to be significantly quicker," Witten said, adding that the HyperPressure's times were from 12 to 100 percent faster.

The company's waterjet doesn't always cut using its highest pressure, though. When cutting metal stock of less than 3⁄16" in thickness and when cutting plastics, the pressure is 55,000 to 60,000 psi. For those applications, Witten said the cutting speed is fast enough at the lower pressure. "You can go from fast to real fast, but it doesn't matter for me when making one or two pieces," he said. "There's no real payback of the added pressure, so we just back it off."

Cutting Calculations

Actual test cuts are the best way to determine what a waterjet machine is capable of, but computer simulations can be accurate because the process "is becoming infinitely more predictable," said Richard Ward, president of WardJet Inc., a Tallmadge, Ohio, waterjet machine builder. "Computer models are integral to any company that wants their customers to succeed straightaway."

Similar to Olsen, Ward feels 60,000 psi "is the most acceptable pressure." This is partly because the 87,000-psi waterjet is a more proprietary product with its array of uniquely designed components than lower pressure systems. "You become more of a captive audience to the manufacturer to furnish their components," he said.

> **'One of the reasons waterjet machining is exploding, and that's probably putting it mildly, is because there's a lot less operator knowledge required to achieve a good finished result.'**

"Our whole philosophy is to have our customers have every alternative to get everything done without having to call us again if they don't want to."

Ward added that there's uncertainty about the cost vs. performance advantages of the higher pressure waterjet for most applications. "If you're cutting one part at a time and never need to cut more than one piece, then 87,000 psi has its merits," Ward said. "If you're looking at doing more than one piece, I'm not sure that the potential costs make it worth going to 87,000 [psi] at this time."

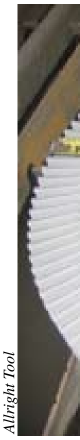
In calculating the cutting speed for a straight, vertical cut with a ±0.010" tolerance when abrasive waterjetting a ½"-thick mild steel workpiece, Ward said he would expect the speed to be 6.4 ipm from a machine with a 60,000-psi, 50-hp pump, a 0.014" orifice and a 0.040" nozzle using 1.4 lbs./min. of abrasive. For a waterjet with an 87,000-psi, 100-hp pump, 0.013" orifice, 0.030" nozzle and 0.8 lbs./min. of abrasive consumption, he calculated a speed of 9.5 ipm for a ±0.010"-tolerance cut.

"If you're comparing one-head cut at 60,000 psi with a 50-hp pump to one-head cutting at 87,000 psi with a 100-hp pump, you are going to cut faster with 87,000 psi," Ward said. "If, however, I take the same 100-hp pump for 87,000 psi and run it at 60,000 psi and put two heads on the machine, I'm going to be cutting at double the speed, or 12.8 ipm, which is about 25 percent faster than the 87,000-psi speed. Single-head, 87,000-psi units will be outperformed by lower-price, dual-head, nonproprietary systems."

Based on testing performed at Flow's laboratory, the 87,000-psi, 100-hp waterjet's cutting speed was 22-plus ipm when cutting ½" 304 stainless steel with a 0.015" orifice/0.040" nozzle combination at 1.5 lbs./min. of abrasive for a ±0.003"-tolerance cut, 19-plus ipm when cutting the same material at the same tolerance with a 0.013" orifice/0.040" nozzle combination at 1.2 lbs./min. of abrasive and 14-plus ipm when cutting the material at the same tolerance with a 0.010" orifice/0.040" nozzle combination at 0.8 lbs./min. of abrasive.

Double Time

Allright Tool Co. Inc., Birmingham, Ala., is a shop that performs abrasive waterjetting with a dual-head configuration and a 60,000-psi, 100-hp pump. Allright Tool has two Jet Edge waterjets: one with a 12'×6' high-rail gantry and a 13'×15' table and the other with a 12'×8' high-rail gantry and a 6'×20' table. Both gantry rail systems have a 6' spreader bar. "We had them custom built to accommodate larger jobs,"



Allright Tool

The following companies contributed to this report:

Allright Tool Co. Inc.
(205) 591-1468
www.allrighttool.com

Flow International Corp.
(253) 850-3500
www.flowcorp.com

Jet Edge
(800) 538-3343
www.jetedge.com

KMT Waterjet Systems Inc.
(620) 856-2151
www.kmtgroup.com

OMAX Corp.
(253) 872-2300
www.omax.com

The Peerless Group
(937) 494-2845
www.thepeerlessgroup.us

Pegasus Northwest Inc.
(253) 854-5451
www.pegasusnw.com

WardJet Inc.
(330) 677-9100
www.wardjet.com

Allright Tool's custom-built Jet Edge waterjet machines have tables measurng 13'×15' and 6'×20' to accommodate large jobs.

said Chris Lentini, Allright Tool's manager. "It allows us to not only cut two full sheets of material at a time, one head per sheet, but to accommodate customers who have a very large diameter object. I can cut a 10'-dia. circle complete."

To maintain pressure when cutting with two heads, Lentini said he uses a 0.015" orifice and 0.045" nozzle combination. When cutting thicker materials—up to 12"—he'll switch to a single head and a larger orifice. "If I increase the orifice to 0.020" when cutting very thick material, it pumps so much water through that jewel that I can't utilize it for two heads," Lentini said. "I just can't maintain the pressure."

The shop waterjets various materials, including induction-hardened steel, Inconel and titanium. On the titanium parts, Lentini noted that the tolerances are within ±0.002" on the cut surface and ±0.001" on repeatability. "I've pushed the limits of the waterjet," he said. "Jet Edge was quite impressed when I showed them the results."

What's also impressive is the amount of abrasive garnet that Allright Tool consumes—44,000 lbs. every 2 months. "I'm probably using more than anybody I'm familiar with in this area," Lentini said. "It's nothing for me to fill a 20-yd. rollaway dumpster in a month."

The shop uses 1.5 lbs./min. per head, or 3 lbs./min. per machine, when two-head cutting. Lentini said the higher abrasive consumption enables a faster cutting speed. "That's how it always worked for me," he said.

Lentini added that he's looked into the 87,000-psi technology, but didn't feel there are enough advantages in relation to the unknown elements. "It's still in its infancy, and I would hate to make a commitment to an unproven technology," he said. "I'm more of a wait-and-see-type person. There are going to be chances for problems that concern longevity."

Mineral Issues

Although garnet can be recycled for repeated use, it represents the largest portion of a waterjet's operating cost. Jet Edge's Schwartz noted that garnet costs, on average, about 20 cents per lb., and, without the abrasive, it costs about $8 per hour to run a midsize waterjet. "That covers the cutting head, the pump, the power, the waterjet consumables," he said. When abrasive is added to the equation, the hourly operating cost jumps to $32 to $35 for a midsize waterjet.

As previously noted, one of the benefits of 87,000-psi waterjetting is a 30 to 50 percent reduction in abrasive use. That's because the abrasive particles are moving faster and therefore carry more energy. "We don't need as much abrasive at 87,000 psi to accomplish the same cutting that we would at 60,000 psi," said Flow's Maier.

At higher pressure, more energy from the waterjet stream is focused on a smaller area, so the more focused jet has greater power density, stated Flow's white paper. The power density increases in relation to operating pressure to the power of 1.5, as expressed in the formula: $E = K \times P^{1.5}$, where E is power density, P is pressure and K is a constant. Using this formula, a 45 percent increase in pressure from 60,000 to 87,000 psi results in a power density increase of 75 percent.

Reduced water consumption is another 87,000-psi benefit, according to Flow, because water flow rate increases along with operating pressure, but at a much lower rate than power density. This means that water is used more efficiently at higher operating pressures.

Maier said Flow planned to introduce the 87k HyperJet pump as a stand-alone version with the WMC waterjet system at the EMO trade show in Germany. And two additional versions of the stand-alone HyperJet 87k pump will be introduced by December 2007 to enable 87,000-psi pumps to be fitted into a variety of waterjet systems, whether from Flow or others. These stand-alone 87k HyperJet systems will be able to operate independently using their control systems.

Opinions may differ about the most appropriate operating pressure for UHP waterjet cutting, but observers agree that the market for waterjet machines is growing as the technology continues to compete more effectively with plasma and laser cutting while providing an easier way to cut difficult-to-machine materials, such as titanium.

In addition, the learning curve to operate a waterjet is relatively short. "One of the reasons waterjet machining is exploding, and that's probably putting it mildly, is because there's a lot less operator knowledge required to achieve a good finished result," WardJet's Ward said. "As a result, I can give a waterjet to anybody to run." △