Abrasive Waterjets:

Harnessing the underwater overachievers

Whether it's blasting through Inconel in minutes or taking thousands of years to erode the nearly 300 miles of the Grand Canyon, the cutting power of water is easily recognizable.

Dr. Norman Franz, a forestry engineer, is widely regarded as the father of waterjet technology. He was the first person to study the use of high-pressure water as a cutting tool. In the late 1950s and early 1960s, Franz experimented by dropping weights onto columns of water and then forcing that water through a tiny orifice, obtaining short bursts of very high-pressured water. It was his goal to create a new tool for the lumber industry, and, although he was unsuccessful, he did prove that highly pressurized water can be used as an effective cutting tool.

From these crude and experimental beginnings, waterjet technology has changed to become one of the fastest growing segments of the production cutting machine industry.

Today, thanks to the addition of an abrasive to the water, the number of applications for this type of cutting continues to grow from cutting hardened tool steel and alloys to glass and ceramics.

In terms of production, where this type of machine really shines, however, is in its flexibility.

"The push toward lean manufacturing will really help the market for waterjets because it is such a great tool. You can start with a plate and make many things out of the same plate with no tool changes and hardly any fixturing," said John Olsen, founder and chief technology officer of waterjet manufacturer, OMAX.

How It Works

After pressurizing the water, usually to between 40,000 and 60,000 pounds per square inch (psi), and then forcing it through a small gem orifice (most commonly a sapphire, ruby or diamond) speeds of 2,500 feet per second are reached. This is equivalent to roughly two-and-a-half times the speed of sound.

Following the passage through the orifice, an abrasive is fed into the water and mixed in a tube. A stream of abrasive-laden water moving at 1,000 feet per second exits the tube and directed at the material to be cut. Since it's the abrasive that is actually cutting the material, it is one of the most important components in the entire system.

"Roughly, half of the cost of running an abrasive waterjet is the abrasive itself," said Olsen. "And, because it is so much of the cost, people sometimes try to get away with buying the cheapest abrasive they can find."

According to Olsen, this is not a good idea as poor quality abrasives can often cause downtime through plugging the cutting nozzle.

The most commonly used abrasive is garnet. Garnet is hard, tough and relatively inexpensive, however, in some cases,


Hard rock garnet

aluminum oxide and other man-made materials are used. Aluminum oxide is harder than the garnet sand, but it is also more expensive and quickly wears out the mixing tube.

"Nearly all of the waterjets use garnet because it is the most effective product," said Randy Rapple, general manager of Barton Mines, one of the largest garnet mining companies in the world. "The garnet quality also plays a huge role in how well the machine performs."

When other abrasives are used, the life of the mixing tubes and orifices are severely reduced. When using garnet, it is not uncommon for a mixing tube to last 60 to 80 hours, however, when aluminum oxide is used, they need to be replaced every few hours.

However, all garnet is not created equal. "Saying garnet is a bit like saying automobile," explained Rapple. "There is a spectrum of garnet products starting with andradite, which is a soft garnet, to almandite, which is a hard garnet. Basically, all of the garnet sold into the waterjet market is almandite."

The best quality garnet is generally blasted and crushed from hard rock deposits, much like Barton's open pit mine in North River, New York. The hard rock garnet is more expensive because of the work associated with the mining process but also performs better due to the sharper angles of the crystals.

Much like sandpaper grit, abrasives come in different mesh sizes. Generally speaking, the courser (and lower-numbered) mesh used, for example a 40 or a 50 mesh, the faster it cuts. The downside of using the course material is that a rougher surface finish is produced.

Waterjet Consumables

Needless to say, the intense pressures and abrasives cause certain parts of the machine to wear and need replacement as a cost of running the machine.

For example, the three common types of orifice gems - sapphire, ruby and diamond - each have their own attributes and lifetime. Sapphire and ruby orifices generally create a good quality stream, and can be used for roughly 25 to 75 hours in an abrasive waterjet system.

A benefit of using a diamond, however, is that this gem has a considerably longer life (800 to 2,000 hours) but is also 10 to 20 times more expensive. They are especially useful in applications where 24 hour per day operation is required.

Usually, orifices will fail because they have been damaged by the small particles hitting them.

"As soon as the orifice is damaged, stream quality is spoiled. If you have a very poor orifice, it will quickly wear out the mixing tube, so the operator has to be aware of the stream quality or they will wear out mixing tubes very quickly," said Olsen.

Other Consumables

The mixing tube adds the abrasive to the high-pressure water, accelerating the abrasive particles. They, like the orifices, and other products that come in contact with the water, need to be replaced.

While the operational costs involved in running a waterjet machine can be high when compared to

other processes-roughly $25 per hour, plus the cost of the operator-the flexibility of the machine, short set-up times and high productivity can help justify the purchase.

Other consumables that need to be taken into consideration when purchasing a waterjet are water and power.

The water usage by the machine is actually quite low, depending on the application, but the same contaminants that cause boiler scale (iron, silica, etc.) will cause problems for waterjet nozzles as well. Also, fine particles in the water will cause problems for the orifice and also with some of the pump components. If this is the case, a reverse osmosis unit is needed in order to help clean the water before it enters the system.

Also, in hard water areas, which are areas where the ground water contains calcium and magnesium, a water-softening unit can be added to the system.

As the cost of electricity rises it is important to keep consumption down. One way to do this is by selecting the correct type and size of pump.

All waterjet pumps work by pushing a plunger into a closed volume and expelling the water. What makes the difference is how you push the plunger. One type uses a crankshaft to push it and another uses a hydraulic cylinder.

According to Olsen, the hydraulic pumping systems have overall power efficiencies in the 60 to 70 percent range, but the crank drives run in the mid-90 percent area. This means that if you are running a 50 HP hydraulic drive unit, you're using more power than you really need. To drive the same jet might take only a 30 HP crank drive.

According to Joe Cisar, senior applications trainer for waterjet manufacturer Bystronic, another way to move the return stroke of the piston is by using air pressure.

"We have a new type of intensifier available that is called active pressure control, or the APC pump, and what it does is eliminate some of the hydraulics that are involved with creating the water stream," he said. "Until now, we have used two hydraulic pumps - the larger one, which is used to compress the water within the cylinder and the smaller one which is used to return the piston back and drawing water into the cylinder at the same time."

Now, he said, the smaller one has been replaced in order to help reduce the amount of electricity that is used. It has been replaced by an air pump and it is now air pressure that returns the piston back and draws in new water, rather than two sets of hydraulics.

"Every customer is looking to save on the cost of operation whether it be electricity, manpower or consumables," added Cisar.

Benefits and Applications

According to Olsen, one of the real strengths of a waterjet system is the very short time required to program and set-up the machine to make a part.

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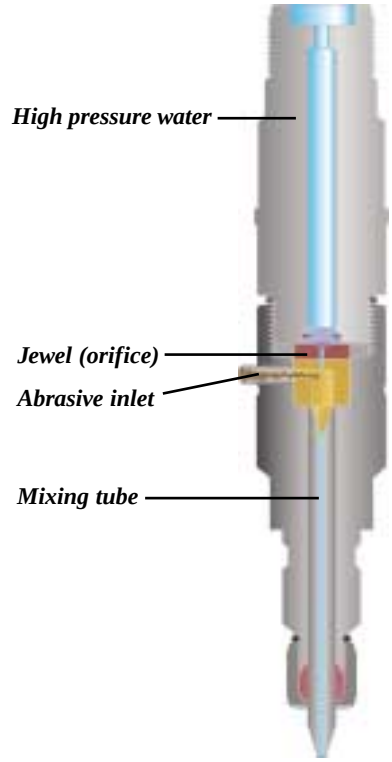
A part that takes a full day for an experienced programmer and machinist to program and set-up on a more traditional machine may only take a few minutes to do on a waterjet. For this reason, they are ideal for short-run parts or prototyping.

Because the abrasive waterjet uses only water and abrasive to do the actual cutting, the material is not heated during the cutting process. This makes the process ideal for materials that are affected or deformed by heat, such as titanium. Another advantage is that when compared to laser, there is a lower purchase cost involved, which can be helpful to a shop owner who is currently farming out work to a laser shop that can then be kept in-house.

While not as fast as laser or high definition plasma on gauge thickness mild or stainless steel, when you compare the cost of a waterjet to the capital costs involved with the purchase of a laser, or the secondary work needed to clean up plasma work, the final cost per part from a waterjet can make it a good addition to a shop.



"There is a little bit of overlap as far as competing with a laser is concerned," said Olsen. "A laser cannot cut near the thickness that a waterjet can, nor can it cut stone or glass. But, the waterjet cannot compete with the speed of a laser in thinner materials."

According to David Dumas, sales manager of Jet Edge, the St. Michael, Minnesota waterjet manufacturer, waterjets and lasers can complement each other on a shop floor.

"On two inch material, I can cut a lot faster with a waterjet than a laser," he joked. "A laser can't cut through it. But as far as plasma or lasers are concerned, they are going to be much faster, but with plasma and laser, you have to worry about secondary operations."

Future of Waterjet

"I think you'll see pressures increasing, bringing up the speed and also multiple head cutting. New advances in the cutting heads themselves will also be able to produce tighter tolerances," said Dumas.

"The word is getting out more and more about the benefits of waterjets. In the past it

was considered expensive and not reliable. It has come a long way since then," he said.

According to Bystronic's Cisar, waterjet systems will begin using more automation as they start being used in producing higher volumes.

"You are going to see a lot more people start looking at the high production end of waterjet cutting," said Cisar. "These will be people who want to constantly run the machine, not necessarily the shops that want to make one or two parts or use it for prototyping."

If you're planning on running constant production on materials that can't be machined by conventional means, waterjet is a very good option, he said. Also, with new, high production applications will come the need for automation to become involved in the process.

"With our new shuttle table feature, we are pushing toward lights-out production," he said. "What the waterjet does is lower the water level, release a safety and the tables exchange, allowing a customer to continue with production without having to stop work or any interaction from an operator."

Waterjet is poised to be a great lights-out machine and it's great for thick plate materials or materials that you can't cut with any other machining process and that's one fact to remember that it can cut virtually any material.

You're basically using the two forces of nature that erode - water and sand.

For more information, please visit www.barton.com, www.bystronicusa.com, www.jetedge.com and www.omax.com.■

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