How HyperPressure™ Drives Cutting Efficiency Through Waterjet Velocity

By Chip Burnham

Benefits of Waterjet Technology

Waterjet technology has been one of the fastest growing, non-traditional machine tool processes in the world for the past 20 years. In the early 1970's, pure waterjet cutting systems were developed to cut soft materials such as corrugated cardboard, gasket, plastic, paper, and foam. Later, the abrasive waterjet entered the scene and began being used for cutting hard materials such as metals, stone, composites, glass, and ceramics.

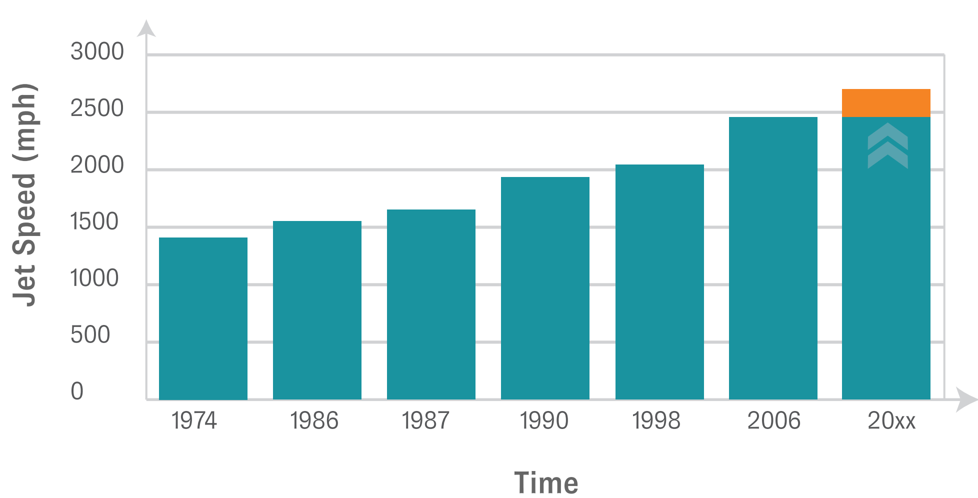
There are many reasons for the rapid acceptance of waterjet technology. It is a cold-cutting process that can cut virtually any material without adding heat or stress, and is extremely easy to set up and operate. These advantages allow manufacturers to produce small or large batches of parts quickly for even their toughest projects.

HyperPressure vs. Normal Pressure

When ultrahigh-pressure (UHP) waterjets were first introduced, pressures were in the 36,000 psi range. Every decade since, pressure has increased, moving to 55,000 psi by the end of the 1980's, and reaching the current standard of 60,000 psi in the mid 1990's. In 2004, Flow International introduced the HyperJet pump, rated at 94,000 psi, into standard manufacturing environments. This breakthrough began the era of HyperPressure cutting with waterjets.

HyperPressure is defined as pressure at or greater than 75,000 psi. With abrasive waterjet cutting, it is actually the abrasive particles within the waterjet stream that erode the material and make the separation cut. The water is the abrasive accelerator. Higher pressure increases the kinetic energy of the abrasive particles contained within it. Water and abrasive particles move faster, the jet diameter becomes smaller, and the jet's power density and efficiency increases.

Figure 1



Manufacturers quickly discovered that when compared to other pumps that operate at approximately 60,000 psi, the HyperPressure pump dramatically improved productivity. Just as increasing wattage increases CO_2 laser cutting productivity, increasing pressure significantly improves waterjet productivity.

However, beyond the approach of raising pressure, many other alternatives to improve productivity were attempted: increasing the horsepower, running multiple heads, using very aggressive abrasives, and optimizing tool paths, to name a few. Of these, the only improvement that has held true is the optimizing of tool paths. Today, advanced waterjet machine tools have tool path optimization that speed up on straight lines and slow down on tight geometry to control finished part anomalies caused by stream lag and also to shorten part cycle times. Even more advanced systems have taper compensation where an articulated wrist tilts the head over slightly to compensate for the naturally occurring V-shaped taper produced by waterjet cutting. The other attempts did not produce efficiency gains for a number of reasons. Increasing horsepower cuts faster but demands a proportional amount of additional abrasive, driving costs up. Adding heads splits the power between the heads doing little for throughput and requiring the operator to ensure both are cutting at precisely the same level. Using more aggressive abrasive drives up operating costs by virtue of the high abrasive cost and also the rapid erosion of the mixing tube nozzle (5 to 10x faster).

Pressure = Productivity

Raising the pressure improves efficiency. Increasing pressure speeds up cutting and reduces cost per inch. At 60,000 psi, the garnet abrasive accounts for over half of the machine operating cost. Running continuously at 87,000 psi, the abrasive cost falls to less than half. Pierce time – the amount of time to drill a start hole – is dramatically reduced as well.

Shorter cycle times mean more parts produced per hour and more jobs completed per day. Fixed cost such as building space, overhead, and equipment depreciation are covered faster which adds to bottom line profitability.

Higher pressure also enables greater cutting detail due to the smaller stream diameter. Maintenance is easier since the new pump is designed for fast, foolproof maintenance with a special high-speed pressure loading tool provided with the pump.

More energy from the waterjet stream is focused on a smaller area, making the abrasive particles more efficient. In other words, each abrasive particle performs more erosion. That power density increases in relation to operating pressure to the power of 1.5 is expressed in this formula:

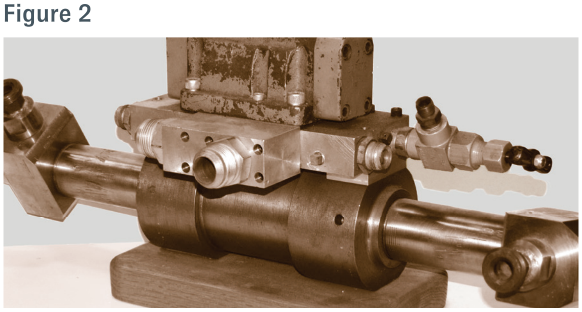
$E_{da} = KP^{1.5}$ where

E_{da} is power density

P is pressure

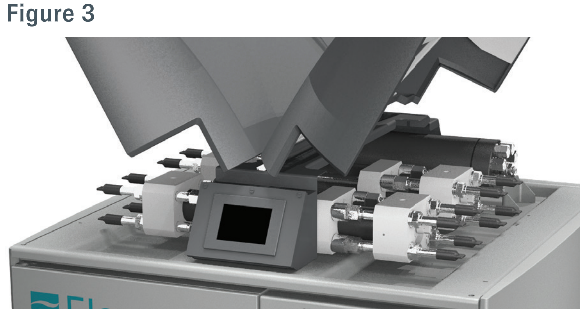
K is a constant

Figure 2



Flow's first commercial waterjet intensifier at 30,000 psi, 1972

Figure 3



Flow's HyperPressure™ pump rated at 94,000 psi

HyperPressure waterjets are ideal for high production environments and where fast turnaround is required. It is also perfect for applications where precision parts are required, since the 25% smaller diameter stream enables more intricate inside corner cutting – commonly down to a 0.015 inch radius.

Velocity Matters

Pressure equals productivity and efficiency because of jet velocity. Why is that so? As pressure goes up, the speed of the stream increases. Once the stream exits the orifice, it's all about velocity. There is no pressure in the waterjet stream once it exits the cutting head; pressure in the water has been converted to velocity as the water exits the waterjet orifice. A faster and smaller waterjet stream means the abrasive particles move faster, carry more momentum, and remove more material, more aggressively. Less abrasive is used per length of cut because each grain can erode more material. The goal is to make the abrasive go as fast as possible. Stream velocity is the key to efficiency.

The only way to make a waterjet stream go faster is to raise pressure – not through increasing horsepower. This might seem counter-intuitive, but it is true. Every pump has a maximum operating pressure so to gain the benefits of a higher velocity stream you must have a pump designed to operate at higher pressure.

Increasing Water Velocity by Raising Pressure

Dr. Mohamed Hashish, who led the team that invented the abrasive waterjet in 1979, has discussed the correlation of water velocity to pressure in numerous technical papers he authored over the decades. His graph below (Figure 5) illustrates that key relationship. The abrasive is pulled into the cutting head from very low velocity via a venturi effect (a way of creating suction) and then accelerated down the mixing tube by the supersonic water (Figure 4). Therefore, the abrasive speed is governed by the water speed. As Dr. Hashish says, "Increasing power by increasing the pressure and not the flow rate gives us the benefit of increased velocity."

Figure 4

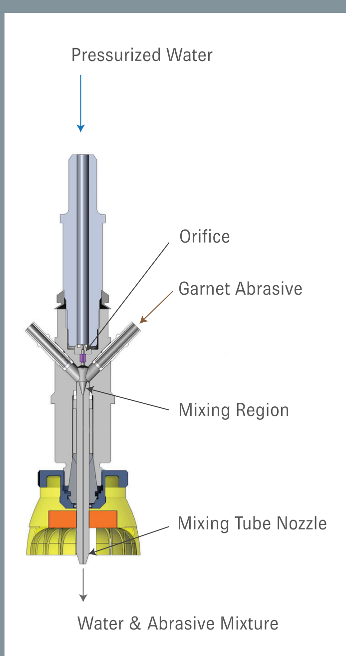
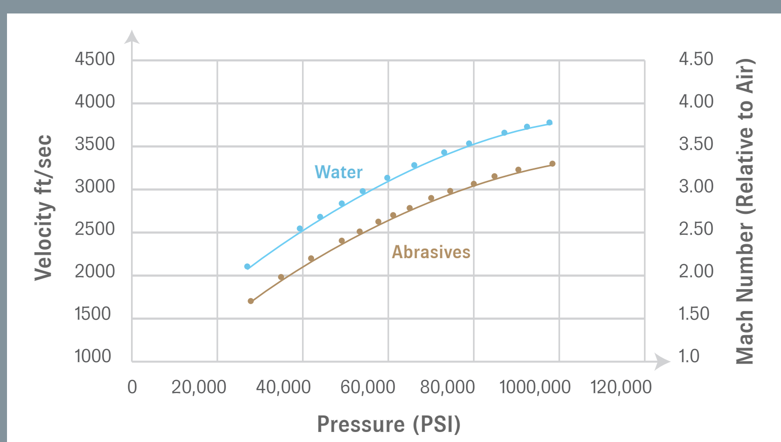


Figure 5



Here is an example of improved efficiency through velocity. The abrasive consumption of a 60,000 psi pump running at 50 hp is the same as a HyperPressure 87,000 psi pump running at 100 hp. The difference is that with the HyperPressure pump, the stream - and thus the abrasive - travels much faster and cuts at approximately twice the speed. This means the garnet use – the main cost driver – is cut in half per minute and even less per inch, making the HyperPressure system more efficient than the lower pressure pump. If we were to hold the horsepower constant, the HyperPressure pump would use nearly half the abrasive and cut at a slightly faster speed as the 60,000 psi system – again showing a dramatic improvement in efficiency.

Cost per Part, Cost of Ownership

The 94,000 psi rated pump running continuously at 87,000 psi should provide higher returns than lower pressure pumps. HyperPressure delivers more efficient cutting, and that efficiency improvement relates directly to lower part cost. Parts come off the machine faster and use considerably less abrasive per length of cut. What is less obvious is the fact that the HyperPressure pump is actually the easiest and fastest to maintain, compared to 60,000 psi intensifiers or rotary direct drive pumps.

HyperPressure pump seals are contained within an easy to handle seal carrier. A pressure loading tool provides not only quick opening of the pump, but also assures proper alignment during re-assembly. Advanced materials, foolproof design, and full array of diagnostic sensors allows maintenance to be performed on a preventative maintenance schedules that maximize uptime ease of scheduling of service. Such predictability of maintenance intervals enables owners of HyperPressure pumps often elect to use OEM service contracts for maintenance. Today more manufacturing shops are outsourcing machine maintenance due to difficulty of finding qualified maintenance personnel, maximizing equipment uptime, and peace of mind.

The Future of Waterjet

Pressures have risen steadily throughout the history of waterjet technology. It is expected that that trend will continue with a 25-30% increase in pump pressures in the next five to ten years. The waterjet stream velocity will go up accordingly, further increasing cutting efficiency.

There will also be a clear split in systems that are designed for higher productivity and lower productivity. Pressure will play a significant part in that split. Since 80% of manufacturers will need higher productivity - and more importantly efficiency - to stay competitive, the proliferation of HyperPressure systems will continue to grow.

About Flow International

Flow International Corporation is a global technology-based manufacturing company committed to providing a world-class customer experience. The company offers technological leadership and exceptional waterjet performance to a wide-ranging customer base. Flow International benefits many cutting and surface preparation applications, delivers profitable waterjet solutions, and provides dynamic business growth opportunities to our customers.