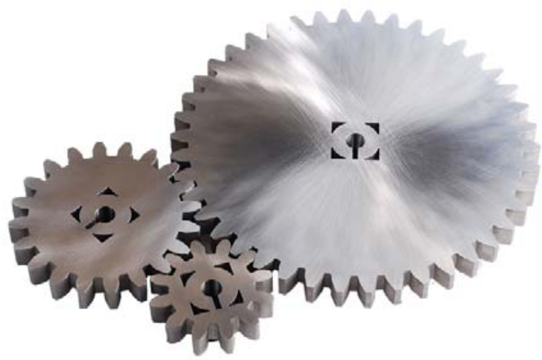

Faster Abrasive Waterjet Cutting from Better Control and Higher Power

By Axel Henning

Abrasive Waterjet Cutting has proven to be an effective and economical process for separating virtually any material. Today, applications of abrasive waterjet cutting can be found in many different industries and range from producing very small high precision parts to making rough separation cuts of 6” steel plates. OMAX Corporation has taken the lead in addressing precision cutting through its Intelli-MAX® Software. This patented control software uses advanced computer models of the abrasive waterjet cutting process and sophisticated control strategies to provide the fastest cutting possible, especially for production of high-quality complex contours with many corners and radii.

To assure the highest possible performance for its users, OMAX is engaged in an ongoing program of development and improvement of the Intelli-MAX software and is currently releasing the newest generation of its cutting model in the Intelli-MAX Software v12.0. With this upgrade (available, as always, to all OMAX customers at no cost) cutting performance and quality can be increased significantly. Production cycle time savings of up to 25% are possible with no changes in cutting parameters or system hardware.

To permit even greater increases in productivity, the cutting parameter range of the cutting model in the Intelli-MAX software has been extended to accommodate larger high-power cutting nozzles with up to a 0.020” diameter orifice size. Such a nozzle can accept the combined output of two OMAX Model 4055V pumps, thus doubling the cutting power available at the nozzle. This opens the potential for new and existing OMAX users to further increase their productivity, particularly for cutting larger parts and in thicker material. A second pump is easily retrofitted to existing single pump OMAX systems and can be used to deliver double the power to a single large nozzle (0.020” orifice), while also permitting full-power operation of dual standard nozzles (0.014” orifices) and also providing complete power unit redundancy.

A dramatic example of the power of the new cutting model in the new Intelli-MAX software and the dual-pump setup can be seen in the title picture. All of the gears shown were cut from 1 inch thick stainless steel and had the same cutting time of 1 hour. The difference is that the small gear was cut with the previous generation cutting model in the Intelli-MAX software and a standard 0.014” orifice nozzle; the medium gear was cut with the new Intelli-MAX version 12.0 software and a standard 0.014” orifice nozzle; and the large gear was cut with the new software and with a high-power nozzle with 0.020” orifice and dual pumps. This demonstrates the considerable effect of the new software and even more the additional cutting performance that can be obtained with a DUAL pump setup.

The Cutting Process

The actual cutting process is the same with all three setups noted previously. There are some basic physics that govern the power of the jet and therefore the performance of the cutting operation. High pressure water passes through an orifice, forming a high speed stream of droplets that are used to accelerate entrained abrasive particles. The amount of pressure determines the speed of the water at the orifice, and the size of the orifice determines the water flow rate and therefore the amount of droplets.

The hydraulic power of the jet in the form of high speed water droplets is used to accelerate the abrasive particles in the nozzle mixing tube. The hydraulic power P_{hyd} of the jet can be calculated from the formula[1]

$$P_{hyd} = p \cdot \dot{V}_W = \frac{p \cdot \dot{m}_W}{\rho_W}$$

The kinetic power $P_{P,kin}$ of the abrasive particles is expressed by the formula

$$P_{P,kin} = \tfrac{1}{2} \dot{m}_P \cdot v_P^2$$

where v_P is the speed of the particles and $\dot{m}_P$ is the abrasive feed rate. Knowing that the particles are accelerated through droplets of water, the speed of the particles can be calculated from its momentum transfer with the acceleration efficiency η_P and the abrasive load $R = \dot{m}_P / \dot{m}_W$ to

$$v_P = v_W \frac{\eta_P}{R+1}$$

The speed of water v_W at the orifice is governed by pressure p and the density of water ρ_W resulting in $v_w^2 = 2p/\rho_W$. The kinetic power of the abrasive particles and therefore the cutting power can be expressed as

[1] Nomenclature of the formulas is explained at the bottom of the paper.

$$P_{P,kin} = \frac{\eta_p^2}{(1+R)^2} \frac{\dot{m}_P \cdot p}{\rho_W}$$

At the optimal abrasive feedrate $\dot{m}_{P,opt} = R_{opt} \cdot \dot{m}_W$ it becomes clear that the optimal kinetic power is determined by the applied hydraulic power, as shown in the resulting equation

$$P_{P,kin,opt} = \frac{\eta_p^2 \cdot R_{opt}}{(1+R_{opt})^2} \cdot P_{hyd}$$

The achievable kinetic cutting power therefore strongly depends on the efficiency of acceleration and selection of the optimal abrasive load. This governs the amount and the speed of the abrasive particles, which determines the cutting performance of the process as can be seen in Figure 1, where the achievable cutting speed for a Q3 quality cut is displayed. When only a few particles are entrained in the jet, they are accelerated well but do not cut well because of their small number. With increasing the abrasive feed rate cutting performance rises significantly until there are just too many abrasive particles to be effectively accelerated. At this point cutting performance begins to degrade. Consequently an optimal abrasive feed rate $\dot{m}_{P,opt}$ for maximum cutting performance can be identified. The achievable cutting performance also strongly depends on the design of the cutting head and selection of parameters. The smaller the mixing tube diameter (and thus the diameter of the jet stream) and the longer the mixing tube, the more efficient the acceleration of the abrasive particles can take place and the better performance can be obtained.

The cost to cut the part is also presented In Figure 1. It becomes clear that it is very beneficial to choose the right abrasive consumption. A too small abrasive feed rate does not give the necessary cutting performance. Too high of an abrasive feed rate adds to the abrasive consumption cost and therefore leads to a higher cost per part. The economically most efficient operation can be found at a slightly lower abrasive feed rate than that for maximum cutting performance.

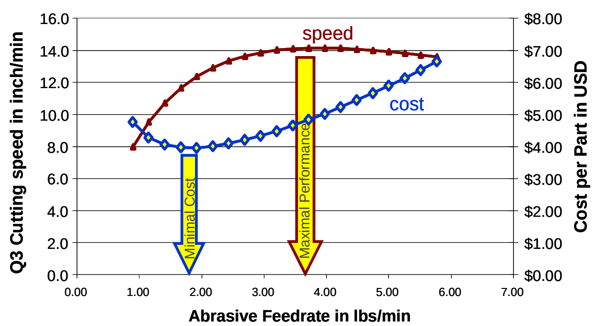

Figure 1: Cutting speed and Part Cost of cutting at different abrasive feed rates

The knowledgeable user can choose to operate at the most economical point or the fastest point or at a compromise point between the two, depending on his cost and production-rate requirements. This is already considered in the Intelli-MAX software version 12.0.

Operating the highly optimized Maxjet® 5 nozzle assembly allows the most efficient operation at the optimal selection of parameters.

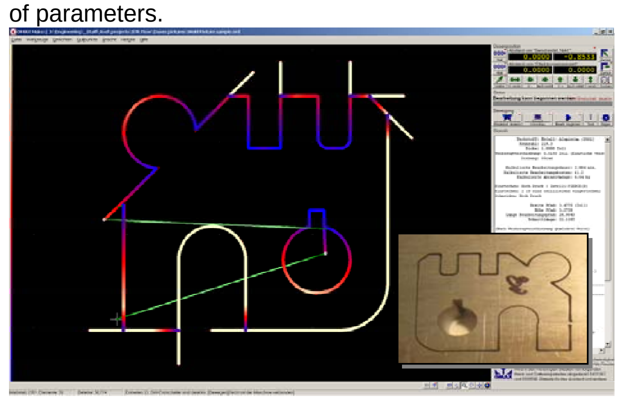

Figure 2: Typical Part in 1" thick aluminum

Cutting at higher hydraulic power

Different approaches have been used to maximize the kinetic power of the jet in order to achieve maximum cutting power at minimal cost. Hydraulic power can be increased by either increasing the pressure at the nozzle or increasing the water flow rate by using a larger orifice. Using higher nozzle pressure is very efficient when high speed water drops alone can be utilized without abrasive for cutting softer materials such as rubber. However, for cutting materials that require abrasive, more significant increases in cutting speed can be obtained by increasing the water flow rate through use of a larger orifice nozzle. With a higher water flow rate the amount of effectively accelerated particles can be increased, allowing significant increases in abrasive cutting speed. With higher water flow rate at traditional ultra-high-pressure (UHP) pressures in the 55 ksi range, standard components such as pumps, valves, tubing and fittings can be used that have proven characteristics in terms of reliability and expected life. The user can operate at high flow rates using a dual pump setup without any significant changes to his machine and can therefore easily switch between standard and high power operation. This allows him to select the optimum operation for the demanded task. Even when only operating at the lower power of just one pump he can still achieve high efficiency, since this pump would still be operating at its optimal point. At this point direct drive pumps can typically achieve an efficiency of 85% (compared to 65% for intensifiers at optimal operation). Thus a dual pump system operating in a standard UHP pressure range can offer the cutting power and speed of an extreme high pressure system, while preserving the efficiency and reliability of a direct drive pump and standard UHP components.

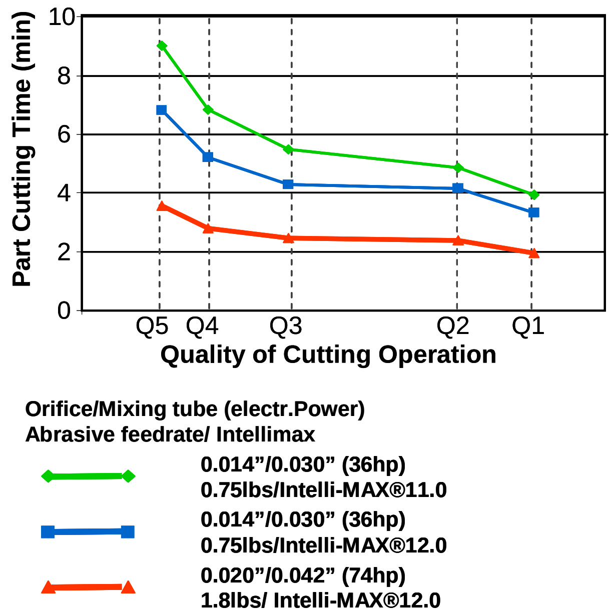

Figure 3: Part Cutting time at different configurations

Comparison of real part cutting

When it comes to real operation the time to finish a part is more important than the maximum achievable speed. With the introduction of the Intelli-MAX software in 2002, all OMAX customers could gain significant production time advantages through its patented jet control, advanced cutting strategies, sophisticated cutting algorithms and elimination of the need for any trial-and-error programming. With the introduction of Intelli-MAX v12.0 with the Generation 3 cutting model, all OMAX customers can now benefit from even further improvements resulting in significant reductions in cutting time.

Rather than only looking at some theoretical maximum separation speed, Figure 2 shows a comparison of cutting real parts as would be done in real shop operations. Figure 3 shows the total time spent to cut this part for the different quality settings. Of course cutting at lower quality settings results in a rougher cut (from Q5 to Q1) but also reduces the part cutting time to a large extent. More significant changes can be seen when comparing the different cutting conditions.

The green line indicates the time needed with a traditional 0.014"orifice/0.030" mixing tube nozzle combination at 55ksi with the previous version 11 of the Intelli-MAX® software. The blue line shows the cut time for the same part using the same nozzle parameters and the new Intelli-MAX v12.0 Generation 3 cutting model. The red line shows the addition of a high-power nozzle with a 0.020" orifice and 0.042" mixing tube, utilizing the power of a dual pump setup, to deliver high cutting power at traditional pressure. With just the Intelli-MAX v12.0 software upgrade the time for this part could be reduced by approximately 20%. With the addition of the DUAL pump setup the part time could well be cut in half.

Summary

OMAX has been successful because our customers have been successful. Our continued success depends entirely on their continued success. To this end we see it as our mission to continually develop and offer the leading edge technology needed to keep our customers on the leading edge of their respective industries. OMAX believes that WORKING SMART is the new paradigm that emphasizes the necessity to carefully assign the available resources to obtain the most benefit in the abrasive waterjet machining industry. All OMAX customers can benefit from our latest advancements in more efficient high power cutting by either 1) utilizing the new and improved features of the new Intelli-MAX v12.0 software upgrade only, or can gain even more by 2) easily upgrading their JetMachining® system to the energy efficient DUAL pump technology to dramatically increase nozzle cutting power. This approach will be of particular value to those OMAX customers who are finding the need to cut larger and thicker parts at maximum efficiency.

Nomenclature

$\dot{m}_W, \dot{V}_W$	Water flowrate (mass, volume)
$\dot{m}_P; \dot{m}_{P,opt}$	Abrasive feedrate, optimal
P_{hyd}	Hydraulic power
$P_{P,kin}; P_{P,kin,opt}$	Kinetic Power of particles, optimal
p	Water operating pressure
$R; R_{opt}$	Abrasive load, optimal
ρ_W	Density of water
η_P	Particle acceleration efficiency
v_P	Particle velocity
v_W	Water velocity at orifice

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