Critical Facts about Ultra-ultra-high Pressure Abrasive Waterjet Cutting Systems

There has been a lot of discussion about the benefits of moving to higher and higher water pressure in abrasive waterjet (AWJ) cutting systems. It has gotten to the point that you now hear statements such as "Everybody knows that the secret to faster cutting is higher pressure". However actual cutting test data and user experience show that such statements are incorrect and misleading. In fact experienced AWJ users who have tried 90,000 psi (90ksi) systems are now moving back to more traditional 55,000-60,000 psi (55-60ksi) systems at a net increase in production speed with reduced operating costs, reduced system downtime and higher profits. Here is why.

Some Basic Physics

The notion that increased pressure means faster cutting ignores the following two basic facts about the AWJ process:

1. Power is proportional to pressure times volume flow rate (P=kpV). For a given pump power any increase in pressure must be matched by a decrease in volume flow rate. More simply put: "You can't get something for nothing". This means that a higher pressure pump must use a nozzle with a smaller orifice. For example a 50 Hp intensifier pump that would use a 0.014" nozzle orifice at 60ksi is constrained to just a 0.010" orifice at 90ksi.
2. In AWJ cutting systems the abrasive does the cutting, not the water. The only purpose of the water is to accelerate a quantity of small abrasive particles in a coherent stream that can erode the material being cut. The smaller diameter waterjet that comes from a higher pressure system may be more effective in water-only cutting applications (such as food products or foam rubber) but it is not more effective at entraining and accelerating the quantity of abrasive particles needed for AWJ applications.

The Net Effect

The bottom line effect of these two factors, as shown in actual head-to-head cutting tests, is that there is very little net difference in cutting speed between traditional AWJ pressures in the 55-60ksi range and ultra-high pressures in the 87-90ksi range, as long as pump power and abrasive flow rate are kept the same. This is true over a wide range of materials and a wide range of thicknesses. For some materials the lower pressure systems may actually cut faster by a bit and for some materials the opposite may be true, but in all cases the straightline separation cutting speeds are very close. Table 1 below shows some typical test results which are confirmed by actual system users:

Table 1: Comparison of Separation Cutting Speeds (inches/min.)-- 60ksi vs. 87ksi with same electric input power and same abrasive flow rate							
					Separation Speed		
Pump	Pressure (ksi)	Orifice Size (inches)	Abrasive Flow (lb/min)		1" thick alum.	2" thick alum.	2" thick steel
50 hp Direct Drive	60	0.015	0.8		19.7	7.7	3.0
50 hp Intensifier	87	0.010	0.8		17.2	6.5	2.6
100 hp Direct Drive	60	0.022	1.4		30.1	12.4	4.0
100 hp Intensifier	87	0.015	1.4		25.0	9.4	3.7

Operating and Maintenance Costs

Experienced 87-90ksi users now confirm what has always been assumed: The operating and maintenance costs of 87-90ksi systems are considerably greater than those for 55-60ksi systems. Not only are pump maintenance costs greater due to shorter component life and the need for more frequent seal changes, but also balance-of-system costs are considerably more than many users anticipated. Surprising to some has been the greatly reduced mixing tube life for 90ksi nozzles. Mixing tube suppliers now typically recommend only their highest quality (and most expensive) mixing tubes for use in 87-90ksi systems and even with that, 30 hours is considered a very good life. Other components subjected to 87-90ksi pressure, such as tubing, valves and fittings, are seeing reduced life and greater susceptibility to unpredictable fatigue failure. This has the dual negative effect of increasing maintenance costs and increasing unplanned system downtime. Worst of all, if a user tries to reduce his maintenance costs by running an 87-90ksi system at lower pressure, he finds that he is still limited to a small nozzle because the hydraulic side of the intensifier is flow-limited and just can't stroke fast enough to provide the volume needed for a full-sized nozzle. Now he is stuck with an expensive pump operating wastefully at lower pressure and using an undersized nozzle that results in greatly reduced cutting speed. His only real solution to this problem is to purchase a new pump designed for higher flow/60ksi operation.

Abrasive Costs

One of the myths of 87-90ksi operation is that abrasive costs can be reduced. However, as shown in Table 1, cutting speeds at the same pump power and abrasive flow rate are essentially the same for 87-90ksi systems and 55-60ksi systems. Sometimes a particular project may put a high value on speed even at some increase in operating cost. For such

situations the traditional 55-60ksi system has the clear advantage of having a large enough nozzle to accept higher abrasive feed rates if desired. For example, merely increasing the abrasive flow rate from 0.8 to 1.0 lb/min for the 50 hp direct drive pump shown in Table 1 can increase the cutting speed in 2" aluminum by about 10% in those cases where higher cutting speed is more important than higher operating cost. The user of a 55-60ksi system is not required to go to greater abrasive flow rates, but he certainly has the ability if desired, and he can very accurately determine the costs of doing so in advance.

Part Production Time

One of the unfortunate side-effects of the attention that has lately been paid to operating pressure and maximum straightline cutting speed is that a fundamental fact has been forgotten: cutting speed alone does not determine production time.

Just as some people tend to fixate on top speed as the measure of an automobile's performance, so it is only natural to fixate on maximum cutting speed as the measure of an AWJ cutting system's performance. However, just as a race is not won by top speed alone so is production time not solely about top speed. Without a skilled driver a high-speed car is just an unguided missile. The skill of the driver is what wins the race. Similarly the "skill" of the motion control system can be the key to making parts quickly and accurately. This is not to say that straightline speed is unimportant, particularly in making large parts with long straight runs in thick material. However, the truth is that the more complex and intricate a part is and the greater the need for precision, the less important maximum speed becomes in determining its overall production time and the more important the effect of good intelligent control becomes. This is all because of the way the jet stream bends as it moves and the resulting complex motion control strategies that have been developed to account for it. The bottom line is that the only way to really evaluate the performance of any AWJ system is to perform time studies and test cuts on actual parts that are representative of a specific user's applications.

Figures 1 and 2 below show the results of two such comparisons and demonstrate the dramatic impact that control software can have. Figure 1 compares a relatively simple part made with an AWJ cutting system using a 50 hp direct-drive 55ksi pump and advanced control software and the same part made with another system using a 50 hp 87ksi intensifier and a less-advanced control software. Made at an equal level of quality, the production times for both parts are quite similar. Figure 2 compares a much more complex part made with the same two machines. The time advantage of the 55ksi system with the advanced software is dramatic. This is a clear example showing the effect that control software can have.

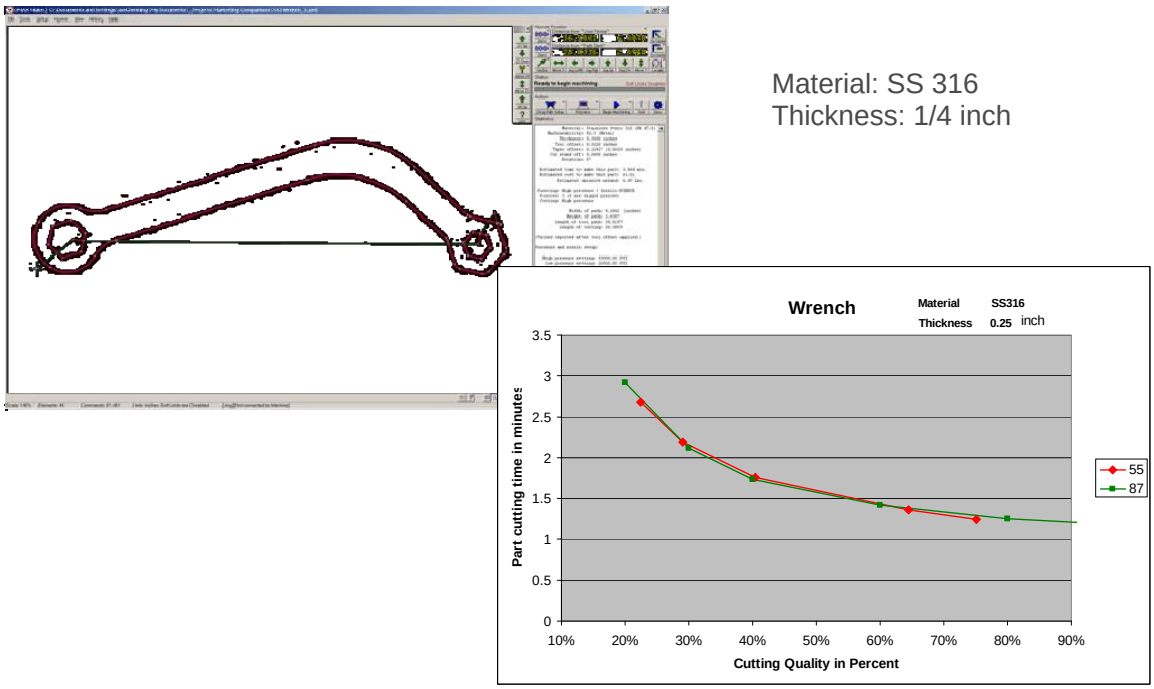

Fig1: A simple part and virtually no difference in cutting time

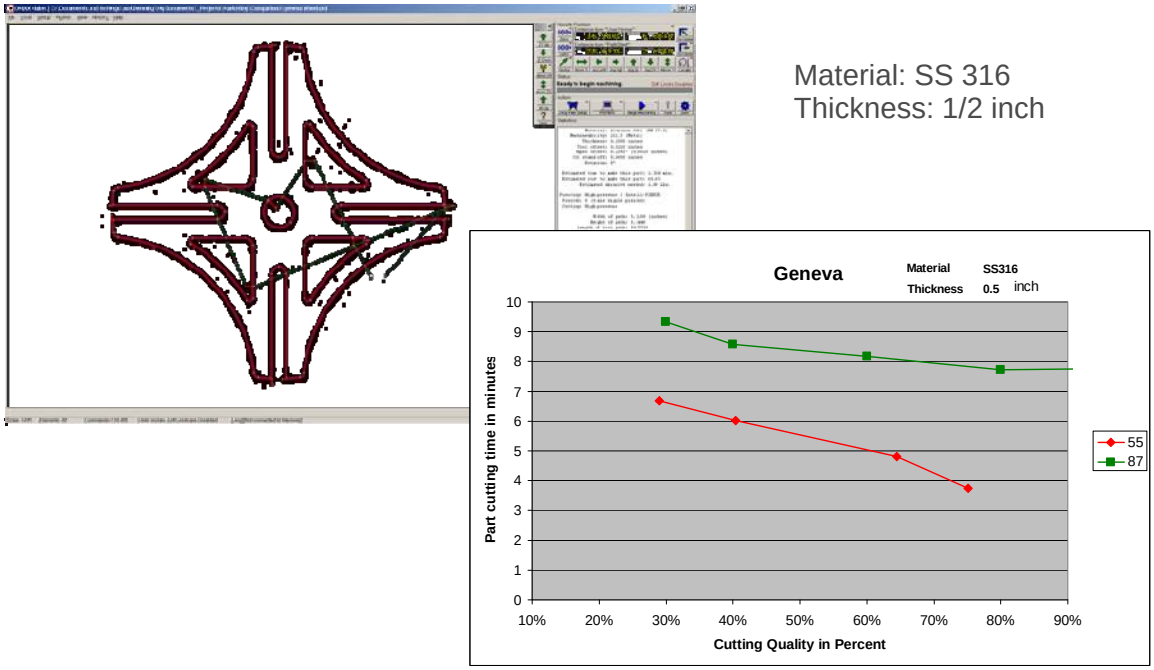

Fig.2—A more complex part shows the clear time benefit of advanced software control

What is the real key to AWJ performance?

Experienced AWJ users are concluding that the key to faster more economical AWJ performance is not the use of ultra-ultra high pressure. Indeed, for a given pump power and abrasive flow rate the increase in pressure only increases costs and system downtime with little if any increase in cutting speed. Rather, the secret to performance seems to be reliable economical operation at traditional pressures in the 60ksi range, combined with advanced control software to minimize production time.