TECHNI Waterjet

Cutting Through The Marketing Hype

There are a lot of claims and counter claims of “the world’s fastest waterjet cutting machines” being made in the world of waterjet cutting. Most refer to the debate over higher pressure with a single nozzle versus higher volume with multiple nozzles. This article looks through the “marketing hype” to the basic principles that govern waterjet cutting speeds, and more importantly looks at the “cost per part” or “cost per inch (or mm) of cutting” to determine the most efficient use of this amazing technology.

Table of Contents

Relationship Between Increased Pressure and Cutting Speed........ 1-2

The Cost of Higher Pressures... 2

Choosing the Best Cutting Head Set Up... 2-4

Reducing the Labour Costs...4

Direct Drive Technology...4-5

Conclusion... 6

Relationship Between Increased Pressure and Cutting Speed

As pressure increases the power requirement increases proportionately and therefore with a given amount of available power the flow rate must be proportionately reduced, by using a smaller orifice, as shown in the commonly used formula **P (Power) = p (pressure) x q (water flow rate).**

For example, a 50% increase in pressure will require a 50% increase in power unless there is an equivalent reduction in flow rate (using a smaller orifice). Higher pressure gives an increase in cutting speed for a given amount of power, as higher pressures and lower volumes result in higher velocity of the water leaving the cutting head, which is a more efficient transfer of power to kinetic energy (the energy used in the cutting process).

This efficiency comes about because increasing velocity is a more efficient way of increasing the kinetic energy stored in the particles of abrasive hitting the work-piece. This is illustrated through another commonly used formula **$E=M V^2$**, where by increasing the velocity has a squared affect on the kinetic energy, compared to increasing the mass which has a linear affect. Therefore, in theory if we increase the pressure by 50%, but decrease the volume by 33% we use the same amount of power but get an increase in the velocity of 50%, which has the effect of increasing the kinetic energy by 48.5%, as illustrated in the formula **E=0.666** (33% reduction in water mass) x 1.5^2 (50% increase in velocity) therefore **E = 1.485** (48.5% increase in kinetic energy). However, this illustration is only relevant for Water Only cutting, as the mass of the abrasive has not yet been taken into account.

Abrasive cutting dramatically increases the cutting capabilities of a waterjet by accelerating the abrasive particles at the work piece where each particle takes out a small gouge of the work piece material during impact. If all the abrasive particles were to hit the work piece in the same condition, but at the higher velocity, the same equation as above would be true. However, the major factor that affects what actually happens is that the abrasive particles get smashed to a very fine powder when hit by the high velocity water stream during the initial introduction of the abrasive to the stream, and more gets destroyed throughout the focussing tube [1]

The intensity of the disintegration of the abrasive particles depends on the water pressure. The result is that at 60,000psi, only about 45% of the abrasive material reaches the work piece in an affective cutting condition. This % drops to about 22% (or less depending on the quality of abrasive) at 90,000 psi. The net result is that there is therefore only a very small net increase in cutting speed when pressure is increased, for an equivalent amount of power. ***This***

[1] ***Changes of garnets during abrasive water jet generation and cutting of materials Martinec, P as presented at the 12th International Conference on Jet Cutting Technology; Rouen; France; 25-27 Oct. 1994. pp. 543-551. 1994.***

can be illustrated in simplified terms for 60,000psi as E=0.45 (45% effective garnet) x 1^2 therefore E=0.45, and 90,000psi as E=0.22 (22% effective garnet) x 1.5^2 (50% increase in velocity) therefore E=0.49, or a 9% increase in cutting speed for a 50% increase in pressure.

The Cost of Higher Pressures

Another important consideration before deciding to increase pressure is the significant increase in the capital cost, maintenance cost, consumable cost and increased machine downtime.

Pressure (also known as force or load) has a non-linear relationship with fatigue-related wear, and for many mechanical machine components, it has a cubed (x^3) relationship. For example, the ISO formula for calculating bearing wear is

L = (C/P)3

L = life

C= rated load

P = actual load

That means that a 50% increase in pressure will reduce the design life of many mechanical components by about 70% or adversely by reducing pressure by 33%, say from 90,000psi to 60,000psi, the life of many components will increase by 330%.

As a result, in order to make pumps and cutting heads that last for reasonable amounts of time at extreme pressures like 90,000psi, manufacturers are forced to use very expensive exotic materials, because metal fatigue becomes the dominant failure mechanism.. The cost of components and consumables that experience high pressures over 66,000psi (such as dynamic and static seals, check valves, tubing and high- and low-pressure cylinders) are therefore typically 50-300% higher than standard waterjet components.

The other factor in the pricing of such components is competition, as only a few manufacturers are currently capable of producing those parts that are resistant to wear and failure at high pressures. As a consequence, the competition to bring down prices doesn't yet exist.

For instance, a standard focussing tube rated to 60,000psi sells for approx. $100, while a 90,000psi rated tube sells for around $300. Moreover, even with the more exotic and expensive components designed for 90,000psi, their life remains well below that of traditional waterjet parts operating with up to 60,000psi. This means increased down time and higher maintenance labour costs, on top of the higher component prices and more frequent part replacements.

Choosing the Best Cutting Head Set Up

In order achieve optimum cutting conditions, higher speeds and increased efficiency, the machine's cutting head has to be set up as optimal as possible. There are many factors to consider when deciding the best cutting head set up, such as:

- *The cost of abrasive, utilities, consumables, and maintenance,*
- *And how much work you have for your machine, and how much supervision is required.*

First let's consider the common options. For this comparison we will use a 50-hp intensifier as the pump, and 80-mesh garnet as the abrasive. Later in the article we will look into the effect of the different technology pumps, and their effect on costs. The variables to be used are:

• Orifice Size

The maximum size of the orifice is determined by the pressure and horse power (HP) available. As pressure increases the orifice size needs to reduce, and vice versa, as the orifice size increases the pressure needs to reduce. Typically for a 50-hp intensifier the maximum orifice size at 60,000psi is 0.013", and at 90,000 psi is 0.010".

• Focussing Tube Size

Traditionally, focussing tube sizes have been three times the orifice size. This ratio has been shown to be the most efficient ratio, giving optimum focussing tube life for material removal. This was established as the industry standard back in the 1980s when focussing tubes were extremely expensive, typically four to five times the current prices.

Today, this ratio is being questioned and many experienced waterjet users, as well as some manufacturers are now advocating a ratio of 2.5 as the optimum. The reasons for this are simple: The more energy you focus over a smaller area, the higher the power density which leads to faster cutting speeds and reduced garnet use. A simple way to look at it is that the same amount of material is being removed except the width of the cut is reduced (the kerf), while the length is increased.

The downsides are that focussing tube life is reduced, and blockages can be more common if poor quality and inconsistent garnet is used. However, with the current price of focussing tubes and garnet, a 50% reduction in focussing tube life for a 33% reduction in garnet use and a 10% increase in cutting speed equals a big reduction in "cost per inch (or mm)".

• Pressure

As discussed earlier, pressure plays only a minor role in cutting speeds for a given HP. That being said, it is still important to have a pressure that is high enough to use the full HP of the pump while maintaining a 2.5:1 (or 3:1) orifice to focussing tube ratio, and a high enough velocity to carry enough abrasive to do the cutting.

For example, if you have a 0.013" orifice with a 0.030" focussing tube you will need approx. 55,000psi to use the majority of the 50-hp pump, and to create enough velocity to pull through 0.75lb/min of garnet. When more efficient pumps are used, in particular direct-driven electric servo pumps with variable power control, smaller orifice can be used to create the velocity without any waste of power.

• Garnet Flow Rate

As mentioned above, garnet typically represents the greatest running cost on a waterjet cutting machine. Therefore strategies to minimise the use of garnet such as reduction of orifice to focussing tube ratios are important. The other factor to always remember with garnet usage is that you need to get rid of the waste garnet, which is an often overlooked cost factor.

• Number of Heads

Some manufacturers advocate multiple cutting heads as an efficient use of power, but in reality this has very limited benefits for most waterjet applications. Strictly speaking, a two-cutting-heads set up with 0.010” orifice and 0.030” focussing tubes with 1lb/min garnet at 60,000psi will cut about 40% faster (taking into account two parts are being cut at once) than a single-head set up with a 0.013” orifice and a 0.030” focussing tube and 1lb/min garnet.

The problem is, however, that you require twice the garnet, and your cutting-head maintenance doubles. When one head gets a blockage or requires any maintenance; the entire machine is down while the head is repaired. Moreover, using two cutting heads means that the cutting area is reduced resulting in a limited size of each single part, while twin heads can only be used for cutting multiple identical parts.

Reducing the Labour Costs

Another obvious factor influencing the costs per part or “cost per inch” is labour.

Waterjet cutting machines are commonly used for cutting thick, hard materials with cutting times of many hours. This makes them ideal for unmanned and “lights-out” operation.

However, lights-out operation entails possible dangers, for example if the machine or the cutting head experiences a problem like a blocked focussing tube or garnet supply, a damaged orifice, a worn wear insert and others.

Fortunately, today this danger can be reduced, as some modern waterjet manufacturers offer garnet delivery systems with analogue feedback systems that will determine any of these common occurrences and put the machine into a pause condition and notify the operator via a text message. So “lights-out” operation is possible and feasible today, and using the right technology waterjet cutting costs can be dramatically reduced.

Direct Drive Technology

The technology used to produce your Waterjet’s pressure (traditionally intensifier pumps or direct drive crankshaft pumps) is important to consider when calculating your overall cutting costs.

Direct drive crankshaft pumps have traditionally been marketed for their efficiency, however, they are only efficient while the cutting head is open and the full capacity of the pump is being used. When the head closes while the material is being loaded, unloaded, and re-loaded, or while the machine positions for the next cut, almost all of the energy is directed over a relief valve, literally sending power, water and money down the drain.

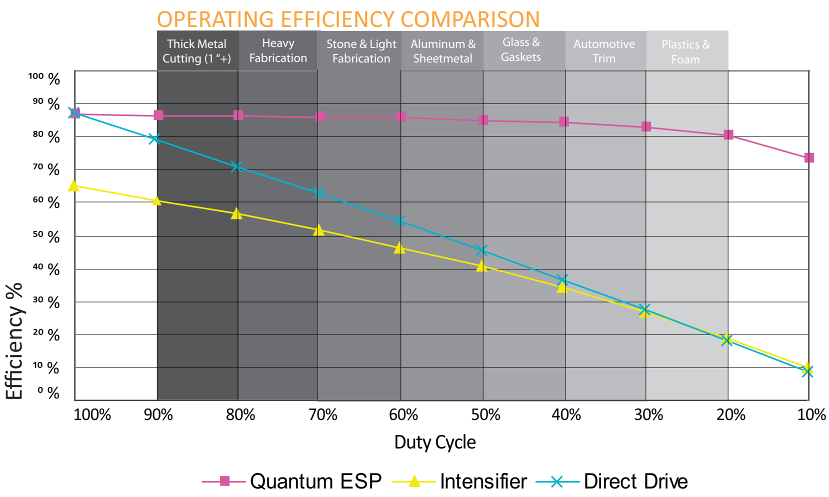
While intensifier pumps can be dead-headed, support multiple nozzles and deliver higher pressures, they are inherently less efficient due to the power required to simply run the hydraulic system. They also use a large percentage of their power regardless whether cutting or idle, as the hydraulic oil is passed over a relief valve in the hydraulic system.

The latest technology emerging on the waterjet market is Electric Servo Pumps (ESP), or Electric Intensifiers. These pumps only ever use the power required for the cutting process. This means that regardless of whether the cutting head is open or closed or the pressure or flow is reduced, there are no additional power losses.

The below graph highlights the increasing efficiency gains achieved with this new waterjet pump technology developed by TECHNI Waterjet, as duty cycles decrease.

Duty cycles equate to the percentage of time that the cutting head is open, cutting, and actually removing material.

As with any profile cutting machine, a percentage of time is used to position the head between cuts and while sheets are being loaded and unloaded. Typical duty cycles range from 90% for heavy plate cutting, down to 20% for plastics, foams and automotive trim components. Most common waterjet applications such as metal cutting, fabrication, stone, and glass run at about a 60% duty cycle.



Conclusion

Waterjet cutting is a unique, versatile and potentially very profitable cutting process. However, buyers and operators need to carefully consider their options to determine the system that best suits their requirements.

By making ill-informed choices, operating costs can double or increase even more for the required cutting task. Taking all the factors discussed above into consideration when deciding for a particular technology, i.e. high-pressure, double-heads, intensifiers or electric servo pumps, will result in the most efficient and cost-effective waterjet system for the respective task.

Below are different machine options, demonstrating the dramatic effect on "cost per inch (or mm)":

Option 1[2]

A 100,000psi 60-hp intensifier pump on a conventional 2-axis abrasive cutting machine, using a 0.010" orifice and a 0.030" focussing tube with 1 lb/min garnet flow.

Option 2[3]

A 60,000psi 2.8l/m electric servo pump on a 2-axis abrasive waterjet cutting machine fitted with an abrasive monitoring device, using a 0.012" orifice and a 0.030" focussing tube with 1 lb/min garnet flow.

Inputs

Garnet $600/tonne (including disposal), water $0.012/gallon, electricity $0.08/kWh, labour $25/hour, cutting 1" aluminium.

Results

Option 1 has a total operating cost of approx. $59/hour for a cutting speed of 10.36"/min or 9.5cents/inch. Or an annual cost of $90,288 to produce 15 miles of cutting (approx. the amount of 1" aluminium plate cut in 1 shift/ year)

Option 2 has a total operating cost of approx. $30/hour for a cutting speed of 11.8"/min or 4.2cents/inch. Or an annual cost of $39,916 to produce 15 miles of cutting.

This represents a savings of $50,372/year from a single shift machine.

[2] *Option 1 cutting speeds come from the advertised cutting speeds presented by KMT in there mass e-mail dated Sept 14, 2010 http://kmtwaterjet.com/pro-100k-cut-chart.aspx*

[3] *Option 2 cutting speeds come from TECHNI Waterjet advertised cutting speed charts.*

TECHNI Waterjet, 47 Barry Rd, Campbellfield VIC 3061
03 9357 8360 www.techniwaterjet.com