Cutting Precious Metals with Abrasive Waterjet

– Tino Volpe • TIFFANY & CO.

ABSTRACT

One would not normally think of using water when a metal cutting application arises. Our nature would be to think that we need something harder and sharper than what we are cutting. Water, if you haven't noticed, is pretty soft, (except for the water in my house, which is hard as nails).

Mother Nature however, might disagree with you. After all, nature doesn't have fancy equipment available when it needs to shape something, such as the Himalayas, so it uses what it has plenty of, water.

Now the idea of cutting with water has been around for a long time, some 3 billion years and there are many fine examples of its effectiveness,

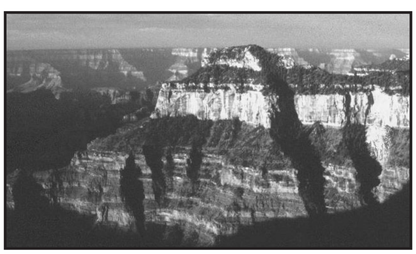

Figure 1: Natures waterjet, Grand Canyon

the Grand Canyon being perhaps one of the best examples. However, nature's process is very inefficient, taking millions of years. In today's bottom line business world, we just don't have that that kind of time on our hands.

In the last 30 years, mankind has figured out how to speed up the process and apply it to a manufacturing environment.

This decidedly non-technical paper will look at the waterjet cutting process and how it can be used in the jewelry industry. It will examine the advantages and disadvantages of the process over traditional cutting processes and as compared to other "high tech" cutting solutions on the market.

HISTORY

Abrasive waterjet cutting came about in the mid to late 70's when quarry companies were looking for a more efficient way to cut stone over the traditional diamond coated wet saws. It was soon discovered that directing a very high velocity narrow stream of water at an object could cut it. No doubt this idea came from watching rivers cut channels.

Figure 2: Niagara Falls

The cutting process can be made more effective by introducing an abrasive such as garnet into the water stream. Today, cutting of stone and tile is mostly done by abrasive waterjet because it is much more efficient and less costly. It also allows the flexibility of cutting intricate shapes not possible with a wet saw. However, waterjet cutting has greatly expanded its presence into almost every industry imaginable. In fact the waterjet machine tool market has emerged as the fastest growing market segment[1].

Water cutting is actually divided into two categories. Waterjet cutting, which is cutting with plain water, and abrasive waterjet cutting (AWJ), which uses water imbedded with a fine abrasive. Plain waterjet cutting is useful on "soft materials" such as plastic, wood, paper, textiles and food. It is widely used in those industries to cut everything from frozen chickens to disposable diapers. When harder materials need to be cut, then the addition of a fine abrasive such as garnet allows one to cut any material whether it be marble or tool steel, and in thickness' up to 8 inches in some cases.

THEORY OF OPERATION

Waterjets work by taking water and compressing it to very high pressures, up to 100,000psi or more, by means of an intensifier pump.

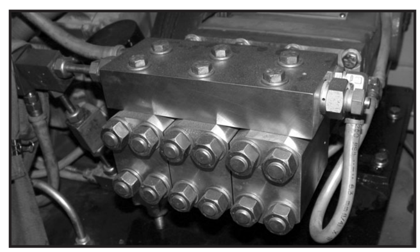

Figure 3: Intensifier pump

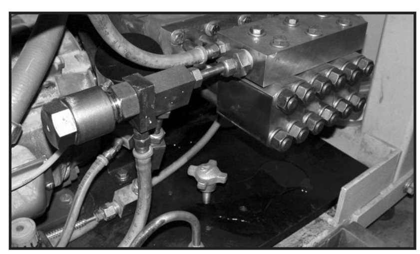

Figure 4: Intensifier pump

Since water is in fact noncompressable, it will be looking to escape somewhere. The highly pressurized water is then directed along high pressure piping through a tiny orifice or jewel. These jewels are typically sapphire and have opening of .0005 to .015 in diameter. The water is forced through an opening by the pressure and will exit at very high velocities, up to twice the speed of sound. When the application is abrasive waterjet, There is a mixing tube employed after the jewel. The water passing through this tube creates a vacuum that pulls abrasive in from a hopper. The jet then exits the mixing tube loaded with abrasive, ready to cut anything in its way.

Figure 5: Head assembly

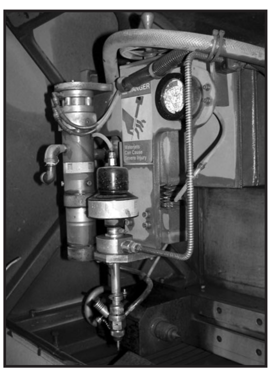

Figure 6: Abrasive jet nozzle

The jet meets the material it removes it by means of supersonic erosion. The quality of the cut can be very fine, depending on the size garnet used, speed of cut, and thickness of material. The waterjet will produce a kerf about 10% larger than the width of the tube orifice.

Typically waterjets and abrasive waterjets are used on flat stock or plates. Beneath the nozzle there is a large tank of water, almost 500 gallons. The purpose of this water is to absorb the energy of the jet after it exits from the bottom of the piece being cut. Without 3 to 4 feet of water to absorb the energy, the jet would eventually abrade through the bottom of the tank! This energy also warms the water to the point that if the jet operated continuously for a full day; the tank can get quite warm. The tank also serves to collect the spent abrasive and metal. This eventually has to be cleaned out. More on that later.

At the top of this tank of water are vertical metal slates, spaced every 2 inches or so. These slates are what support the work being cut. Since they are thin and placed vertically they present a very small profile to the jet, therefore are not cut by the stream and will last a long time.

Because the jet exerts very little pressure on the work piece, very little Fixturing of the material is needed.

The requirements for a waterjet are simple but important, very clean water and even flow and pressure to the pump. Hard water or water with sediment will quickly wear out the check valves on the pump, causing leaking and eventual failure. Starving the pump of water due to poor flow or pressure can damage the pump. Water usage is about .25 gallons per minute. Abrasive usage is about .5lbs. Per minute depending on the size abrasive used. The finer the surface finish one is looking for, the finer the abrasive that should be used. In our case 150 mesh garnet gives a nice matte finish on the parts.

ADVANTAGES

The advantages of using an abrasive waterjet over other methods such as EDM or lasers are many and some of them are significant. For example, AWJ produces no heat-effected zone, as lasers and to some degree EDM does. AWJ can cut any type of material, whether they are reflective, something lasers can't handle well or non-metallic, and something EDM can't touch.

AWJ is much faster than EDM, and can cut much thicker materials than a laser. AWJ produces so little side force compared with conventional cutting tools that you can cut a slice of tubing .0025" wide without any warpage of deflection.

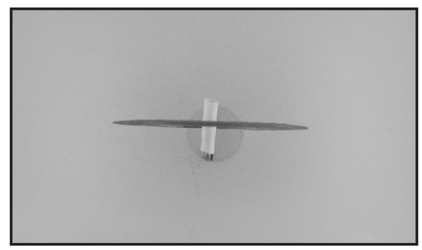

Figure 7: Slice .020" thick

Unlike Wire EDM, no start hole is required with AWJ.

We have only been comparing AWJ to EDM and lasers but in fact, this technology can in some cases replace stamping or blanking operations. Its advantage in that field is that hard tooling for presses takes a long time to develop and can be expensive. This makes stamping a poor choice for low production runs. However, AWJ, although slower than a press in cutting out a blank, let's say for a coining or forming operation, requires no tooling. Also, there are no dies or punches to break or wear out. Through special programming, parts can be separated by as little as a .050" wall, greatly reducing scrap generation over conventional blanking operations. Like an EDM or laser it is program driven and can accept .dxf files from AutoCad, programs.

The programs are windows driven and fairly easy to set up.

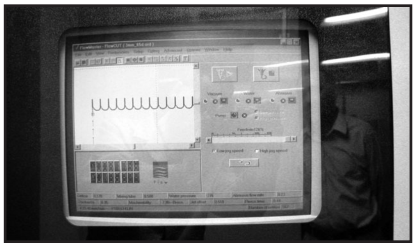

Figure 8: Software tracking cutting path

One should keep in mind that AWJ, like all other "tools of the trade" is not the end all do all technology. Instead, it is becoming a must have compliment to EDM's, lasers, and CNC lathes and mills.

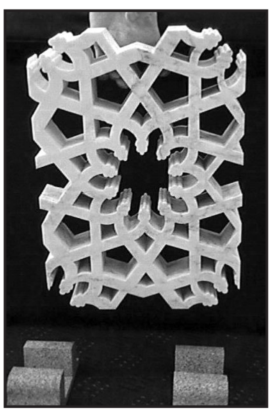

Figure 9: Marble Lattice[2]

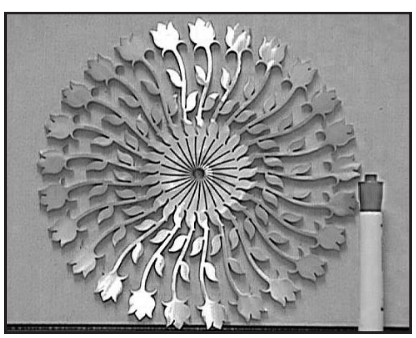

Figure 10: Titanium rose motif[2]

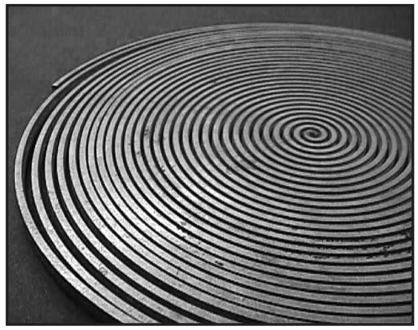

Figure 11: Copper spring cut from solid plate[2]

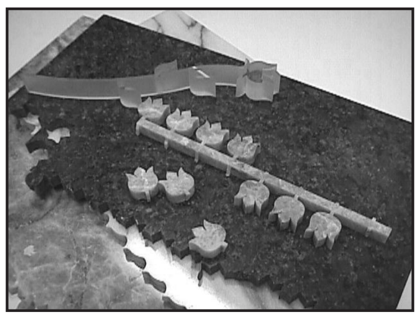

Figure 12: Marble roses, glass rose[2]

CUTTING PLATINUM

As all of us who have worked with Platinum alloys know, it is perhaps one of the most difficult metals to machine. Its very high density and gummy characteristics plays havoc with tooling.

Typically the only way to get superior surface finishes is with PCD tooling, which is quite expensive. However, for any type of cutoff work, such as cutting ring blanks from tubing, PCD cut off tools will not survive. Even typical carbide or high-speed steel tools produce wide kerfs, creating plenty of scrap turnings and taking a fair amount of time. Obviously, the weakest link in cutting platinum is the tooling. What if we could get rid of the tooling? This is where AWJ produces a definite advantage. There is no tooling to wear out and resharpen, and the waterjet doesn't care about Platinum's density or gummy tendencies. It doesn't care about its temper.

Cutting platinum sheet stock is fairly easy and straightforward. It treats it no differently that any other material and in fact will cut it fairly easily and quickly. Cutting tubing is much trickier and will be the focus of this discussion.

APPLICATION

The issue was that all the applications I've seen with waterjet at the time were cutting flat sheet stock. How do you cut a tube? Running the jet straight across the tube will only cut the top 180 degrees. What is really needed is to rotate the tube into the abrasive stream. This would cut the tube in an inward spiral from OD to ID. Working with the manufacturer of the equipment, a lathe was mounted to the inside bed of the machine.

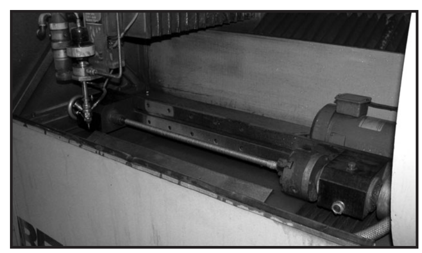

Figure 13: Lathe assembly

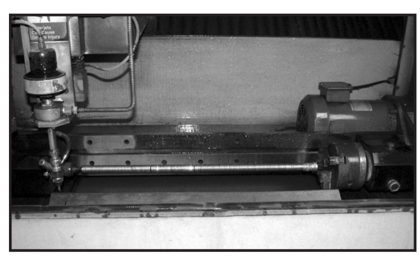

Figure 14: Lathe assembly front view

This lathe was driven by an electric motor (waterproofed of course). The lathe itself was made from stainless steel components. The theory was that the waterjet would slowly advance into the tube as the tube is rotated underneath the stream.

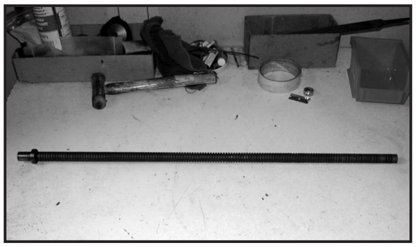

Figure 15: Mandrel

In order to support the tube to keep it from wobbling and to hold the pcs so they wouldn't fall into the tank when cut, a mandrel would have to be employed. The mandrels are considered a consumable item that are made from carbon steel. When the jet penetrates the tube there will be some erosion of the mandrel before the jet pulls out, eventually the mandrel will wear out and will have to be replaced. We have found that a mandrel might last as many as 10 and sometimes 20 tubes before having to be replaced. It depends on how well the programming is set up. You don't want to spend any more time than necessary to cut the tube before pulling out otherwise you are cutting the mandrel and further eroding the tube, making you kerf wider and putting a taper in the cut, which is undesirable. In theory the jet would only have to penetrate the tube a distance equal to the wall thickness of the tube. By programming just the right speed of the jet, one can avoid excessively cutting into the Mandrel.

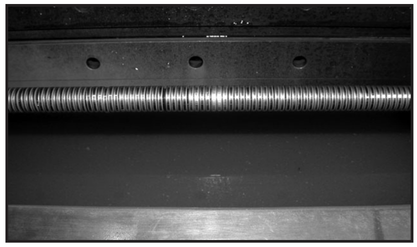

Figure 16: Fully cut platinum tube

The program would be designed to cut into the tube, then pull out and advance a distance equal to the width of blank you are looking for plus the kerf of the jet. For example, if you want to cut a 2.5mm wide blank, you would program the distance between cuts to be 3mm, 2.5mm for the actual blank and .5mm for the kerf of the jet. With this method we were able to cut a platinum blank with a wall thickness of .090" in about 30 seconds. We were easily able to cut 600-700 blanks in an 8-hour shift. In technical terms, the platinum is not being cut but actually eroded away. With the lights dimmed, one can actually see a white hot spot where the jet is making contact with the metal.

Figure 17: Jet making a cut

There are certain issues and inefficiencies that affect the cutting of tubing that are not present when cutting flat stock. One issue with tube cutting is that as the tube is cut the jet stays in the cut for the length of time it takes to cut through the wall. This can cause tapering of the sidewall if one spends too much time making the cut. Also, the jet is at it's most efficient about .020" above the surface of the metal, the farther the distance from the surface the greater the loss of energy and the stream begins to fan out giving us a larger kerf. When cutting flat stock, one always maintains the same distance from the surface, however with tube; the jet makes the first contact with the tube a distance equal to it's outside radius. This is because the z-axis is not programmable therefore the height has to be set manually to clear the tube.

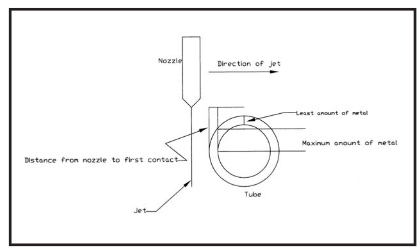

Figure 18: Schematic showing jet in relation to tube

From the diagram one can see that as the jet advances into the tube, the distance between the nozzle and tube surface gets smaller. At the beginning of the cut the jet is at its most inefficient. The program never brings the jet over the top of the tube because to do so would risk piercing the tube and the mandrel before the jet pulls out. One wants to advance the jet only slightly past the inside wall of the tube. This will reduce wear on the mandrel. Then it is just a matter of picking the right speed for the advancing jet to insure it cuts through the tube. Just to note: A programmable z-axis would go a long way to producing a more efficient cut. This option was not available on our machine.

DISADVANTAGES OF AWJ

There aren't many disadvantages to a waterjet. It is a very loud machine pushing 100dBs in sound level so hearing protection is a must as well as its own room.

It produces a matte finish on the cut surface. If you want a bright cut, you're not going to get it. Its water requirements are strict. The water must be very clean, free of any sediment and minerals. If not you will need to filter it and soften it. The machine also needs the feed pressure and flow to remain constant. This is an aftermarket system that is a closed loop system the takes the overflow water, filters it, treats it, refrigerates it and returns it back to the machine. The treated water is purer than the original feed water. This saves water and results in less down time from pump maintenance.

Perhaps the biggest disadvantage of the waterjet, especially for our industry, has to be dealing with the spent abrasive and metal. The tank will eventually fill up with abrasive and need to be cleaned out. This involves shoveling and vacuuming out the wet abrasive into drums. In other industries cutting base metals, this spent abrasive may qualify as landfill material. However, after cutting platinum out abrasive is laden with metal that we want to recover. The richness of that abrasive will be between 2.0% and 3.0%. Each cleanout will yield about a ton of abrasive so that is a fair amount of ounces of metal.

Since most refiners will include a per lb. processing charge along with all the other charges, it is a good idea to dry the abrasive. This can be done with drum heaters and a 30-gallon drum full of abrasive will take two days to dry. The abrasive is then sampled by means of a coring tool (a pipe with one end open) so a representative sample is collected. If all this sounds complicated, it is. However there is good news for the future. There are companies out there that make sediment removal and drying / separation systems. These systems automatically siphon the abrasive out of the tank on a continual basis, then dry, screen and separate clean dry abrasive which can be reused, from the metal and abrasive too finely ground to be of use. Most industries are more interested in recovering abrasive to lower costs.

FUTURE

With the introduction of tube cutting, AWJ is moving beyond cutting flat stock. 3D systems and waterjet milling machines are already on the market. Some highly specialized applications use liquid nitrogen instead of water as a medium, which evaporates leaving just dry abrasive and metal. Indexing chucks instead of rotating chucks would allow cutting fancy shapes into tubing, instead of just slices. The future is indeed looking bright for this technology

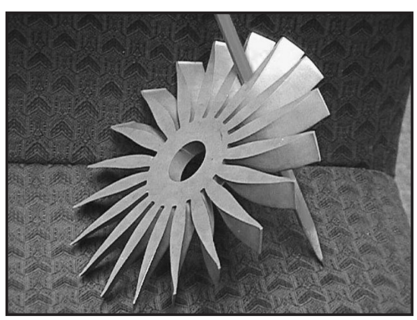

Figure 19: Fanblade cut with 3 dimensional system[3]

CONCLUSION

So, is cutting platinum tubing with a waterjet a better mousetrap. Certainly one will garner plenty of opinion from industry people over which method is preferred, whether it be casting blanks, stamping blanks, machining them or even making them from powder. Our experience from the last two years lead us to feel that in today's market, where product has to be delivered yesterday and labor costs are constantly increasing, we were able to produce 800 rings per day with two people and three pieces of equipment.

Figure 20: Finished blanks

Having an AWJ system was integral in making this manufacturing cell work. The efficiency of the process can not to be overstated. In today's market, efficiency and productivity separate the winners from the losers.

Acknowledgements: Special thanks to Paul Keck for taking the photographs of our waterjet in action. Thanks to Flow International for some of the photographs shown here.

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