Abrasive Waterjet Cutting

Application and Capability

Introduction

Abrasive waterjet cutting is gaining popularity as a means for cutting a wide variety of materials. Ease of programming and the jet's ability to cut almost all materials and any thickness make it suitable for all shape cutting applications except extremely hard materials.   Its most significant attribute as an accurate cold cutting process allows it to cut metals without leaving a heat affected zone.

There are many applications where abrasive waterjet is the superior cutting method. Although waterjet should be considered for all applications, it will not replace conventional cutting methods such as stamping, laser or plasma cutting. It will continue to experience increasing use for cutting a wide variety of specialty materials.

1. Abrasive Jet Process Description

Abrasive waterjet cutting utilizes a high velocity coherent stream of water and abrasive that can be used to cut almost all materials. Water at 40,000 to 55,000 psi accelerates through a sapphire, ruby or diamond orifice. The stream passes through a mixing region where the vacuum, induced by the stream, sucks in abrasive. Momentum of the water stream accelerates and entrains abrasive as it passes through the nozzle. The stream exits the nozzle as a three phase mixture of air, water and abrasive particles with a cutting diameter of 0.020" to 0.060". The high velocity abrasive particles impact on the kerf face and do the actual cutting. Kerf material is removed as microchips, with no negligible affects on the material.

The cutting stream carries 0.5 to 1.5 pounds per minute of abrasive. The quantity of abrasive is dependent on the cutting stream size, which is selected based on the material to be cut. Garnet is by far the most commonly used abrasive. It is environmentally clean, contains no free silica, and combines good cutting ability with reasonable wear on the consumables. Other less commonly used abrasives are olivine sand, silica sand and slag by-products. Due to its high Moh's hardness, aluminum oxide has been rarely used, for cutting of very hard materials. Because of its high hardness aluminum oxide rapidly wears out the nozzle and is expensive to operate. Most shops use the abrasive once and then it is disposed as land fill waste.

The main attributes of the cut are: no heat, narrow kerf, good edge finish, and high accuracy. Successful, cost effective, abrasive waterjet applications take advantage of these characteristics.

2. Benefits of Abrasive Jet Cutting

Abrasive waterjet offers many advantages not found in other cutting techniques.

a. No heat affected zone (HAZ)
b. Low contact force of cutting stream.
c. No distortion and warping
d. Burr-free
e. Can cut any material and thickness
f. Near net shape cutting eliminates secondary operations.
g. Can achieve high accuracy's of up to +/- 0.001.
h. Material thickness of 0.002 to 12" can be cut.
i. Small kerf width allows for tight nesting and optimal material usage.
j. Flexibility

3. Most Commonly Cut Materials

Materials that are reflective, conductive, heat resisting, or heat sensitive are ideal candidates for abrasive water jet cutting. As the material thickness increases AWJ becomes the preferred cutting technique, especially where accuracy must be maintained.

Heat sensitive and heat resisting materials such as stainless steel, alloy steel, titanium, inconel and hastelloy can be cut with no material effects. Some distortion may occur due to the residual stresses already present in the material. In thicker materials (over ¼") the edge finish and cut accuracy are superior to heat cutting methods. There is no burr or dross that may require secondary operations. Conductive materials such as aluminum and copper also cut well. AWJ is the superior cutting method for aluminum because of its high cut speed. Since AWJ is a mechanical cutting process, materials of low hardness and density cut faster.

Reflective materials such as polished stainless steel and polished brass are cut without discoloration along the cut. There may be slight frosting along the cut. This is usually not significant enough to require masking.

Hard plastics are also good candidates for AWJ. Polycarbonate(Lexan™) is an excellent cutting application since it can be cut without edge discoloration, as caused by laser. Acrylic(Plexiglass™) can be cut but it is prone to chipping during piercing. Soft plastics, foams and rubbers can be cut with waterjet, with no abrasive in the stream.

Other materials that are brittle such as stone, ceramic and glass can be cut. Piercing may cause chipping which can be alleviated by piercing at reduced pressure. AWJ cutting of inlaid patterns with stone is a growing market for business and expensive homes. The results are beautiful and unique.

4. Typical Applications

Abrasive waterjet has the ability to cut almost all materials and thickness'. Most uses are for cutting of specialty materials such as stainless steel and aluminum. Its flexibility makes it useful for all applications, but of course some uses are better than others. The following is a list of applications where waterjet is the best approach:

- Shape cutting of ¼" and thicker aluminum
- Net size cutting of ½" and thicker stainless steel
- Blank cutting of parts for final machining
- Short run lots of sheet metal parts
- Screen Cutting
- Converting plate stock to bars
- Precision cuts in ½" and thicker mild steel
- Hardened materials
- Intricate shapes in delicate materials
- Custom shims in stainless steel and exotic materials
- Tube cutting

Note that conventional applications such as sheet metal and low accuracy mild steel cutting are not on this list. Abrasive water jet can do this with quality results but, generally is too expensive compared to plasma, laser or punching.

5. Cut Geometry

Abrasive waterjet cuts have straight edges with a slight amount of taper. Kerf width is controlled by the orifice/nozzle combination. Cuts in thicker materials generally require larger combinations with more abrasive usage. The kerf width can be as small as 0.020" for thin materials and up to 0.055" in thick materials.

The minimum inside corner radius is controlled be the nozzle diameter and therefor is 0.010 to 0.030". Inside corners may have digs on the bottom of the cut in thick materials. This is due to the exit of the stream lagging behind the entrance side of the stream and can occur as the jet exits from corners. Reducing the feed rate or adding a radius of at least 0.5" can eliminate this in thick materials.

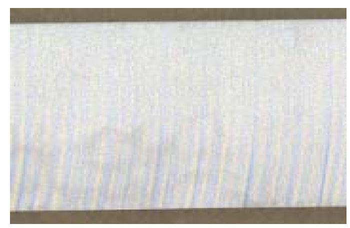
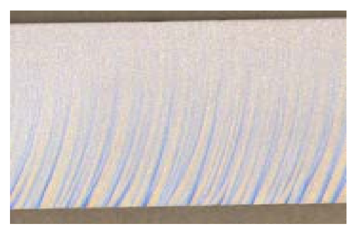
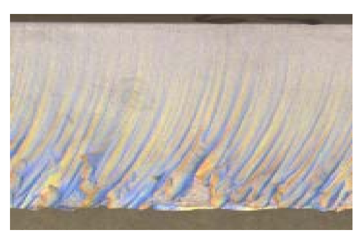
The abrasive jet can pierce or drill holes smaller than 0.060" diameter.

Interrupted cuts can be performed if the distance between the top and bottom layer is less than 1.5". For example 1" OD x 1/8" wall 304 tubing can be cut to length. The benefit of this approach is that there are no burrs as there would be with saw cuts.

6. Cut Quality

Cut quality describes the kerf edge and taper. The feed rate controls the amount of jet lag. Cutting speed and edge quality are directly related. At high feed rates the jet has increased curvature as it passes through the cut. Reduced cutting speeds can result in a good edge finish of 125 microinch, having a ground appearance and minimal taper. High feed rates for separation cuts give striations through the full cut depth.

Edge quality is defined with a scoring system with the numbers 1 through 5.

Edge quality	Cut Appearance	
5	Excellent, no striations, most accurate	
4	Very good, minimal striations	
3	Good, striations on bottom half of cut, most commonly used	
2	Fair with through striations	
1	Poor and rarely used	

7. Edge Taper and Total Part Accuracy

The following chart gives part accuracy and edge taper per side for high accuracy(Quality=5) and normal accuracy(Quality=3) feed rates. These values are based on parts cut on a high accuracy CNC table with tool compensation to at least three decimal places. Higher accuracy's can be achieved but may require sorting.

Material	Edge Taper		Part Accuracy	
Thickness	Quality=5	Quality=3	Quality=5	Quality=3
0.12	0.002	0.005	+/-.003	+/-.005
0.25	0.0035	0.0075	+/-.005	+/-.010
0.5	0.003	0.01	+/-.007	+/-.005
0.75	0.0035	0.012	+/-.010	+/-.020
1	0.004	0.014	+/-.015	+/-.030
1.5	0.006	0.016	+/-.020	+/-.040
2	0.008	0.018	+/-.025	+/-.045
3	0.01	0.02	+/-.030	+/-.050
4	0.012	0.02	+/-.035	+/-.055

8. Comparison to Other Cutting Techniques

Abrasive waterjet cutting is an important shape cutting technique. Generally, it cuts with superior quality than heat cutting methods and with less cost and quality than electrical discharge machining (EDM). The following are key points of comparison:

- The accuracy and edge quality of AWJ is similar to laser for thin sheet metal and superior to all other shape cutting methods, except electrical discharge machining (EDM), in thick materials.
- AWJ is slower than heat cutting techniques in nonconductive materials and similar for conductive materials like aluminum.
- AWJ has almost unlimited thickness capability whereas high powered plasma is limited to about 2" and laser to about 0.75" thick.
- In steel and stainless steel, for thickness' where they compete, the cost per inch of cut for AWJ is higher than laser and plasma because of its lower cutting speed and higher cost of operation.
- AWJ does not create a burr or HAZ as the heat cutting processes do. This saves expenses for secondary operations.

Good AWJ applications take advantage of its unique capability to cut with high accuracy without using heat. These applications justify themselves based on high part quality and the elimination of secondary operations. When all the costs are factored in abrasive waterjet cutting is the most cost-effective solution for many applications.