Academic Journal of Science,
CD-ROM. ISSN: 2165-6282 :: 1(3):275–282 (2012)

WATER JET CUTTING TECHNOLOGY AND ITS COMPARISON WITH OTHER CUTTING METHODS IN SOME ASPECTS

Tolga Mert

Yildiz Technical University

Cutting is an essential process for manufacturing industry. Therefore, over the years, research has kept continuing on various cutting processes including thermal and mechanical methods. In this paper, a versatile and an effective cutting process, which has been developed in recent years, called water jet technology is explained thoroughly. Moreover, this technology is compared with other traditional and non-traditional cutting methods in some aspects.

Keywords: Cutting, Water jet.

1. Introduction

Today, as the competition circumstances get tougher, manufacturing technology demands materials to be cut more precisely and faster. In the last years, water jet cutting has come at first for this purpose. High pressure water jet has been used for surface cleaning since 1968 [1]. Today, in industry, water jet cutting is used for cutting hard and soft materials except for a few hard-to-cut materials like diamond and since it is not a hot process, cut materials are not affected by heat and minimum cutting stresses are introduced compared to other cutting processes [3]. There are no health-related hazardous outputs like fume, gas, dust etc. during cutting process, so it is healthier and more environment friendly compared with other cutting processes [1,2].

2. Water Jet Technology

In water jet process, water is pressurized to a very high level via hydraulic pump and intensifier and it forms a very high pressured steam (4000 ~6000 bar) [4] when focused through a sapphire, ruby or diamond orifice [4,5]. In pure waterjet cutting, the supersonic stream erodes the material with its kinetic energy. In abrasive waterjet cutting, the high velocity abrasive particles, usually garnet, are introduced in a chamber and water with abrasive particles passes through a nozzle, which is made of tungsten or boron carbide and then impact the kerf face and do the actual cutting. Kerf material is removed as microchips [6].

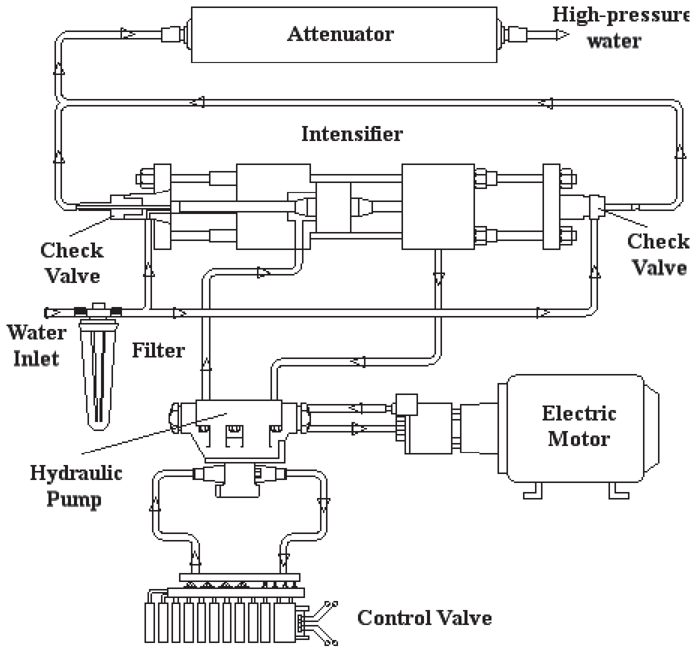

Figure 1. Schematic diagram for water jet technology [1].

Intensifier Pump

In a typical intensifier pump, two fluid circuits exist. These are the water circuit and the hydraulic circuit. The hydraulic circuit consists of a piston biscuit/plunger, manifold, oil reservoir, hydraulic pump and an electric motor. Hydraulic pump is powered by the electric motor and it pulls oil from the reservoir and then pressurizes it to slightly over 200 bars. This pressurized oil is sent to the manifold. Manifold's valves send hydraulic oil to one side of the biscuit/plunger or to the other side and these create the stroking action of the intensifier. The intensifier is a reciprocating pump because biscuit/plunger assembly reciprocates back and forth and delivers high-pressure water.

Figure 2. Intensifier [7].

2.1 Pure Waterjet Cutting

Original water cutting method is pure waterjet cutting and it is usually used for cutting soft materials. Tissue papers, disposable diapers and automobile interiors are the largest use for pure waterjet cutting. It is interesting note that in the case of tissue paper and disposable diapers cutting, waterjet process produces very low moisture on the materials.

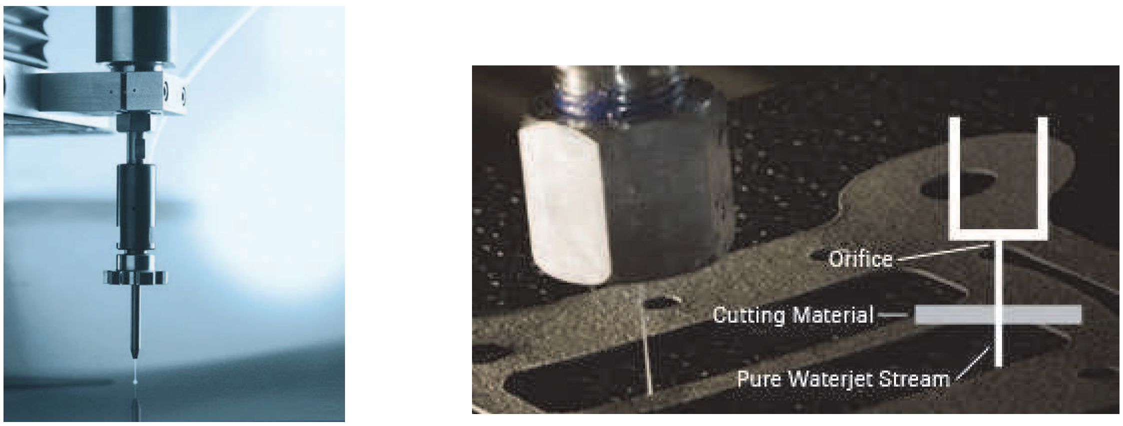

Figure 3. Pure waterjet cutting heads [8].

Pure waterjet has a very fine stream of 0.1 mm to 0.25 mm in diameter and cut not only thick but also thin materials. It produces extremely low cutting forces and it does not introduce heat to material. This process is also able to cut soft and light materials, which may have detailed geometry very quickly [7].

2.2 Abrasive Waterjet Cutting

In the abrasive waterjet, the waterjet stream accelerates abrasive particles and those particles, not the water, erode the material. Therefore, the abrasive water jet is hundreds of times more powerful than a pure waterjet and thus, it is able to cut harder materials, such as, ceramics, composites, metals, stone, marble etc.

Figure 4. Abrasive waterjet cutting head [8].

Abrasive waterjet usually has a stream of 0.5 mm to 1.3 mm and it can also cut geometries with details and it produces no heat affected zone, mechanical stresses and little burr like pure waterjet cutting. In addition to this, abrasive waterjet cutting process is able cut materials with 250 mm thickness.

2.2.1 Abrasives

The most common abrasive in waterjet cutting is almandite garnet (fig. 5). 150-300 µm particle size is common for cutting most of the materials with a good finish. If particle size is lowered then a better quality is achieved. If coarser grade is used for cutting, finish quality gets worse while cutting speed increases [4]. When more abrasive is added to waterjet, first, cutting speed increases and after a certain point it starts to decrease. This is also valid for cost in inverse proportion. When more abrasive is used, first, total cost per inch decreases, then again after a certain point, total cost starts to increase. Since fastest cutting speed means lowest cost per millimeter, one must try to achieve highest cutting speed while maintaining cutting quality [4, 7]. Moreover, high abrasive flow rate does not mean that cutting quality would be high. In fact, there is an optimum level for each setting.

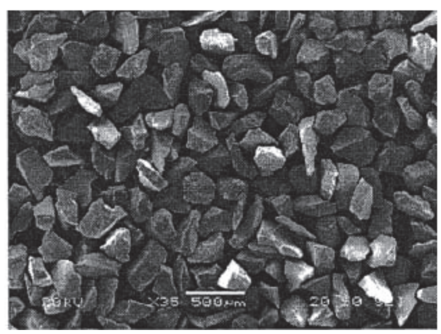

Figure 5. Scanning electrone microscope image of almandite garnet [9].

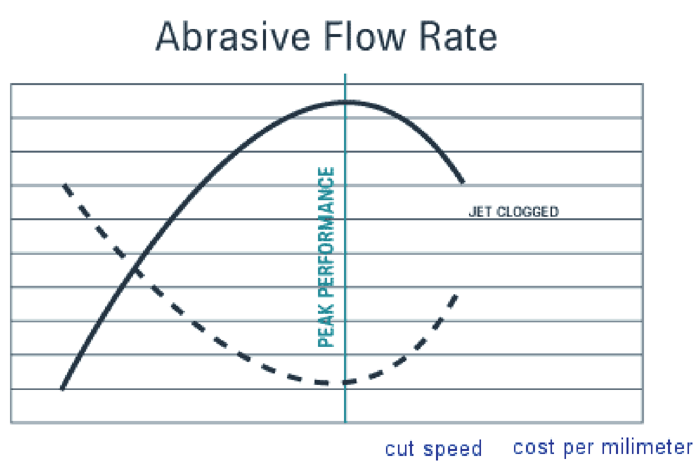

Figure 6. Cutting speed vs. cost per milimeter in waterjet cutting [7].

2.2.2 Effect of Parameters in Waterjet Cutting

Some researchers have studied the effects of water pressure, abrasive flow rate, standoff distance and traverse speed on surface roughness and depth of cut. They found out that when water pressure gets higher, the depth of cut increases; and when traverse speed gets higher, depth of cut decreases. High traverse speed also results in higher surface roughness. When abrasive flow rate gets higher, first, surface roughness decreases and then after a certain point it increases. Similarly, when standoff distance gets higher gradually, first, surface roughness decreases and after a certain point it increases [10, 11, 12].

2.2.3 Some Problems Encountered with Waterjet Cutting and Solutions

2.2.3.1 Stream Lag

When beam type cutters (i.e. laser, plasma, waterjet etc.) cut through the material and power begins to drop, stream deflects in the opposite direction of travel. This ends up with inside corner problems and increased taper. If power is increased and/or cutting (transverse) speed is slowed down then this lag error will be reduced [7].

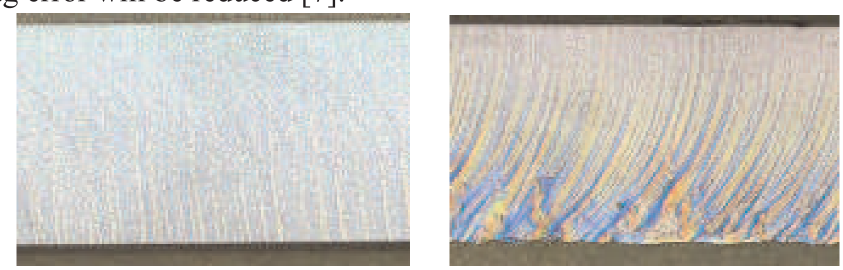

Figure 7. Excellent cut (left), striations (right) [6]

2.2.3.2 V-shaped Taper

If material is cut at high speeds then V-shaped taper is created. Taper can be minimized by increasing the power or slowing down the cut path [7].

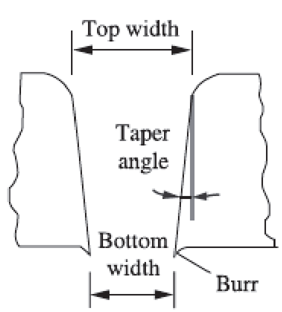

Figure 8. Taper in waterjet cutting [13]

2.2.3.3 Inside Corner Problems

When inside corner is cut at high speeds, the stream can dig into the part when it comes out of the corner. In order to avoid this problem, cutting speed must be lowered [7].

2.2.3.4 Sweeping Out of Arcs

The stream lag sweeps out a cone when material is cut at high speeds. Therefore, cutting speed must be reduced [7].

2.2.3.5 Abrasive Mesh Size

Abrasive mesh sizes have a major impact on cutting speed and surface finish quality. Typical abrasive mesh sizes are 50, 80 and 120. While finer abrasives produce smoother surfaces but slower cutting speeds, coarser abrasives produce faster cutting speeds but coarser surfaces [7].

2.3 Advantages and Limitations of Waterjet Cutting

2.3.1 Advantages

- Short machine setup times
- Easy automation
- Environmental friendly materials are used (water and garnet). Reuse of the abrasive up to 80% is possible [14]. No impurities like oil and emulsions.
- No dust or fume generated
- Loss material to be cut is too small
- Heat generated during the process is insignificant
- Almost no distortions
- One tool for cutting different types of materials and thicknesses
- Can cut very thick materials (over 300 mm) [6, 12]

2.3.2 Limitations

- High speed linear cutting gets a V profile
- Waterjet deviates at high speed cutting of circles and arches
- Waterjet may produce notches at high speed cutting of inner angles
- In cutting of thick materials striations may occur along the depth of the cut due to high transverse speed or insufficient pressure
- Limitations in machining 3D shapes
- Machining very hard materials is difficult
- After cutting, corrosion prone materials need to be protected [12]

3. WaterJet Technology Compared with Other Cutting Techniques

In table 1, waterjet cutting technology is compared with laser, plasma and oxy-fuel cutting in terms of material thickness, cut quality, transverse speed, burring and total cutting time etc. It can be stated that except traverse speed, waterjet cutting is superior or at least equal to laser cutting in all categories.

Table 1. Waterjet cutting compared with other cutting techniques [15].

Category	*Abrasive waterjet cutting*	*Laser cutting*	*Plasma cutting*	*Oxy-fuel cutting*
Material thickness	****	**	***	****
Cut quality	****	****	**	**
Transverse speed	***	****	***	***
Versatility	****	**	***	**
Precision cutting	****	****	***	*
Need for secondary process	****	***	***	**
Burring	***	**	**	***
Production flexibility	****	***	**	*
Total processing time	***	***	*	**
****: Perfect ***: Good **: Acceptable *: Poor				

In figure 9, waterjet cutting technology is compared with laser, plasma and oxy-fuel cutting in terms of material thickness for different types of materials. It can clearly be seen that waterjet cutting is superior to other cutting techniques in terms of material thickness and it is highly flexible in cutting of variety of thick materials.

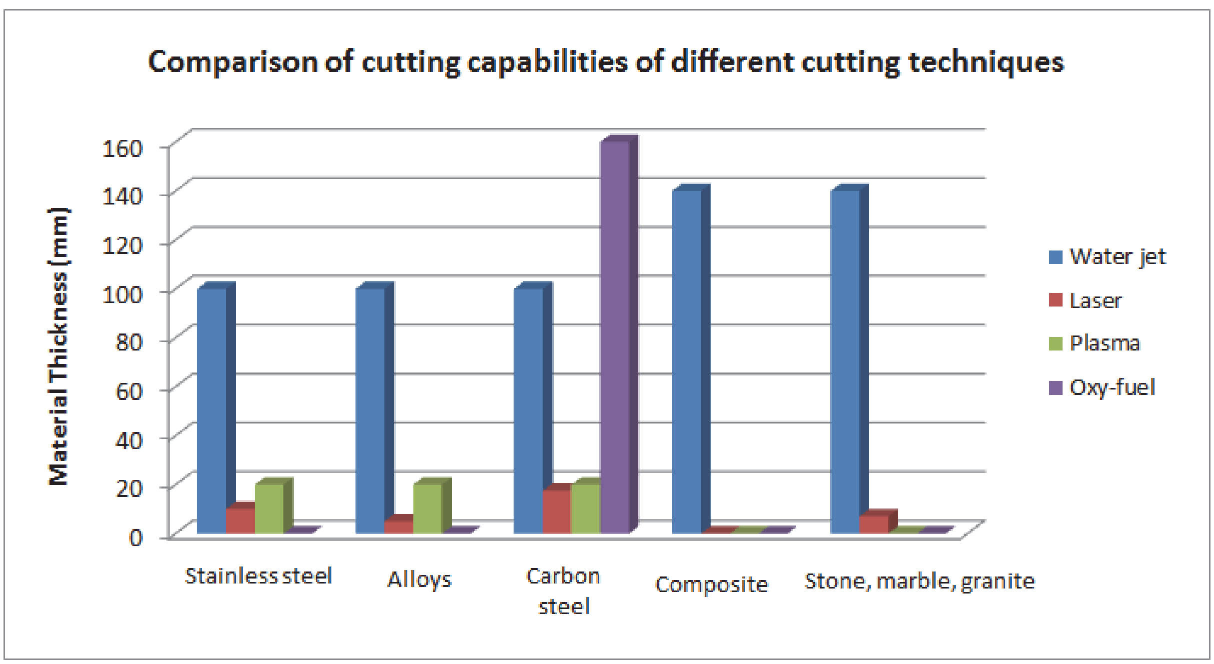

Figure 9. Comparison of cutting capabilities of different cutting techniques [16].

4. Conclusion

Waterjet cutting technology has been one of the most preferred cutting processes lately because not only is it environment friendly but also it is economically feasible. It can cut almost any material up to 300 mm with little or no burring and no heat effect on material to be cut.

Therefore, it has been a serious competitor for high precision and state-of-the-art cutting processes and is likely to continue its development in the near future.

References

1. Akkurt, A., 2004, "Waterjet cutting systems and assessment of their industrial applications", Journal of Polytechnic, vol.7, no.2, pp.129-139.
2. Akkurt, A., 2005, "Effect of cutting speed on surface roughness in AWJ cutting applications of commercial pure aluminium and Al-6061 aluminium alloy", Journal of Polytechnic, Vol.8, no.1, pp.69-79.
3. Selvan, M.C.P. and Raju, N.M.S., 2011, "Assessment of process parameters in abrasive waterjet cutting of granite", International Conference on Trends in Mechanical and Industrial Engineering (ICTMIE'2011), 23-24 December, Bangkok, pp.140-144.
4. Folkes, J., 2009, "Waterjet-An innovative tool for manufacturing", Journal of Materials Processing Technology, 209, pp.6181-6189.
5. Akkurt, A., Kulekci, M. K., Seker, U. and Ercan F., 2004, "Effect of feed rate on surface roughness in abrasive waterjet cutting applications", Journal of Materials Processing Technology, 147, 389-396.
6. FedTech Inc., http://www.fedtech.com/services/abrasive-waterjet.html.
7. Flow International Corporation, http://www.flowwaterjet.com/en/waterjet-technology/.
8. Water Jet Cutting World, http://www.waterjetcuttingworld.com/2011/03/12/water-jet-cutting-machine-8/.
9. Arola, D. and Hall, C.L., 2004, "Parametric effects on particle deposition in abrasive waterjet surface treatments", Machining Science and Technology, vol 8, no.2, pp.171-192.
10. Selvan, M.C.P. and Raju, N.M.S., 2011, "An experimental investigation on depth of cut in abrasive waterjet cutting of aluminium", International Journal of Engineering Science and Technology, vol 3. no.4, pp. 2950-2954.
11. Aydın, G., Karakurt, I., and Aydıner, K., 2011, "An investigation on surface roughness of granite machined by abrasive waterjet", Bull. Mater. Sci., vol. 34, no.4, pp.985-992.
12. Botak, Z., Kondic, Z. and Maderic, D., 2009, "Waterjet machining", Technical Gazette, 16, 3, pp.97-101.
13. Wang, J., Kuriyagawa, T. and Huang, C.Z., 2003, "An experimental study to enhance the cutting performance in abrasive waterjet machining", Machining Science and Technology, Vol 7, no.2, pp. 191-207.
14. Waterjet: A New Approach, December 2008, http://www.modernapplicationsnews.com, pp.18-19.
15. Akkurt, A., 2004, "Su jeti ile kesme sistemleri ve uygulama alanlarının değerlendirilmesi", Politeknik Dergisi, Cilt: 7, Sayı: 2, s. 129-139.
16. Akkurt, A., 2009, "ASJ ile kesilen AISI 1030 çelik malzemeden elde edilen kesik yüzey özelliklerinin diğer kesme yöntemleri ile karşılaştırılması", Pamukkale Üniversitesi Mühendislik Bilimleri Dergisi, 15, 2, 142-152.