CUTTING ERRORS IN ABRASIVE WATER JET CUTTING

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Abstract

The paper presents some practical experience in abrasive water jet set cutting. This cutting technique is modern process which is today, more and more present in industry. It has some significant advantages according to thermal cutting techniques and it becomes important tool in production engineering. Investigations of cutting parameters, as well as surface cut quality, cutting accuracy and repeatability are discussed in this paper.

1. INTRODUCTION

In waterjet cutting, pressure and velocity of water streaming through the nozzle are two distinct forms of energy. Material has been removed due to stream of water that tears away microscopic pieces or grains of material. In this cold cutting process, the waterjet performs an erosion process which "grind" away small grains of material to be cut. Abrasive can be added to the stream to increase the efficiency of the process many times. It is complex technology, because system has to generate and control water at 60,000 psi what is very demanding task, since at these pressures a slight leak can cause permanent erosion damage to components (if not properly designed). Waterjet compliments other technologies such as nonconventional (laser, EDM and plasma) or conventional (milling) processes. There are no noxious gases or liquids used in waterjet cutting. Waterjets do not create environmental hazardous materials or vapours. There is no heat affected zones or mechanical stresses on a waterjet cut surface. Waterjet is a versatile, productive and cold cutting process. Waterjets remove material without heat.

2. ABRASIVE CUTTING

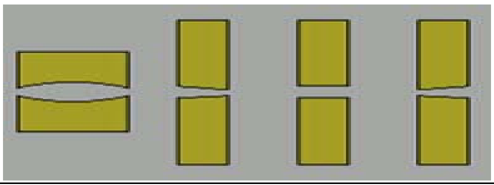
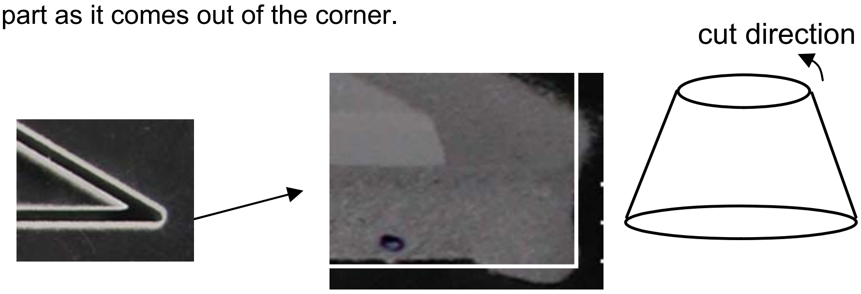
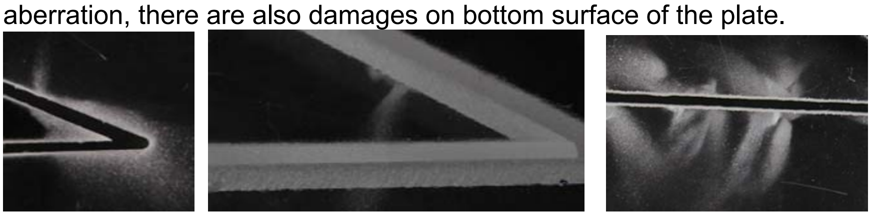
Pure waterjets are used to cut soft materials, while the abrasive waterjet cuts hard materials, such as metals, stone, composites and ceramics. The abrasive waterjet differs from the pure waterjet by means of addition of the abrasive particles which, not the water, erode the material. Therefore is the abrasive waterjet hundreds or thousands of times more efficient than a pure waterjet. Abrasive waterjets can cut materials with hardness up to and slightly beyond aluminium oxide ceramic (AD 99.9). Typical abrasive mesh sizes in abrasive waterjet cutting are 120, 80, and 50. The different mesh sizes do not have a significant impact on part accuracy. They have a greater impact on surface finish and overall cut speed. Finer abrasives (larger mesh number) produce slower cuts and smoother surfaces. In abrasive waterjet cutting it is often thought that if the abrasive flow rate is reduced, process will save money. On the contrary, it wastes money. There is a peak performance point where abrasive waterjets will operate efficiently. Machine operating cost include power, water, air, seals, check valves, orifice, mixing tube, abrasive, inlet water filters, long term spares (hydraulic pump, high-pressure cylinders, etc). Basically, these are all the items that need replacement regularly or over the life of the waterjet system. Abrasive constitutes 2/3 of the machine operating cost of the equipment. When all overhead are included, the cheapest cutting is always found at the fastest possible speed. This fact is independent of the material type to be cut, or the power of the system. Consumption of abrasive is within 0,25 and 0,5 kg/min. Abrasive particles already used has to be washed and dried what allow recovery of 20 to 60 %. Recycling of abrasive accounts for up to 65% of total operating costs of running the AWJ

3. CUTTING ERRORS ESTIMATION

To perform cutting within demanded quality it is of big importance to have a machine as better accuracy as possible but also to have appropriate software to control the machine since good software can increase cutting speed. Tolerance ranges achievable on water jet cutting machines are +0,025 mm to –0,025 mm. Much more realistic is tolerance range +0,05 mm to –0,05 mm. To avoid cutting errors there are several performances to be checked: accuracy and repeatability, maximum contour velocity, travel length and operating pressure. Some results are shown in figure 1.

Dynamic accuracy tests are conducted by either cutting of parts or yet by a device called a Ballbar.

Ballbar testing is included in a number of standards for machine tool accuracy i.e. ISO 230, ASME B5.54 and BS3800. It is accurate to approximate +/- 0.5 microns, or 20 microinches at 20 °C.

Cutting error	Description
Beam Deflection	The stream deflects backwards (in opposite direction of travel) when cutting power begins to drop. This problem causes: increased taper, inside corner errors, and sweeping out of arc. When cutting at high speed around an arc or circle the stream lag sweeps out a cone. 
Tapered cutting geometry	A "V" shaped taper is created when cutting at high speeds and at high depth of material. 
Inside Corner errors	When cutting an inside corner at high speed, the stream can dig into the part as it comes out of the corner. 
Workpiece fixturing errors	Even though the waterjet delivers under 200 N of vertical force when cutting a high quality part and under 2000 N when rough cutting, proper fixturing is required to produce accurate parts. Dou to particle stream and its aberration, there are also damages on bottom surface of the plate. 
Workpiece temperature instability	Some materials, like plastics, can be very sensitive to temperature changes. These materials may expand when material is slightly heated or shrink when cooled. During waterjet cutting the material does not get hot, but it can get warm.
Cutter Comp error	Short nozzles are conducted for cuts with width of 0,5 mm, while if longer nozzles are conducted, width of cut is in the range of 0,076 mm. Cutter compensation takes into account the width of cut of the jet; in effect, you are setting the amount by which you are enlarging the cut path so that the final part comes out to proper size. It is preferred to make a cut tests to establish the best cutter compensation value. 

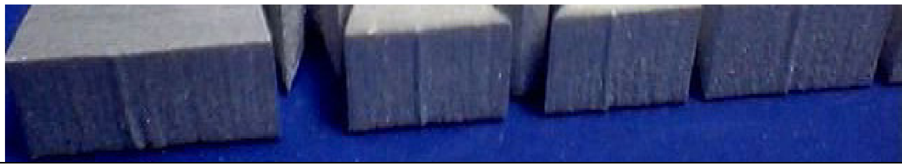
Cinematic errors	There are many aspects to machine motion performance. A few are: backlash, repeatability, position accuracy, straightness, flatness, and parallelism. Oscillation between moving system and material will result with very bad quality. 
Errors due to unsatisfactory pressure during cutting	High pressure errors 
Errors due to unsatisfactory pressure during keyholing	High pressure errors  Low pressure errors (insufficient power to cut material) 

Figure 1. Cutting errors during Plexiglas cutting

Cutting tests were performed on 4 kbar OMAX water jet cutting system with flying cutting head (figure 2).

Figure 2. Cutting system used for tests

The technique allows pure water to pass through a nozzle of small diameter, 0.18 - 0.35 mm, at very high pressure, usually 3000 - 4000 bars.

The water now travelling about 700-850 m/sec, holds enough kinetic energy to cut through any material under this jet. As an energy presenting factor, streaming speed of water can be calculated from Bernoulli equation:

$$v = \left(2 \cdot p \cdot \frac{g}{\rho} \right)^{1/2}$$, where is:

p - nominal output pressure, Pa

ρ - specific mass, $\frac{\mathrm{kg}}{\mathrm{m}^3}$

g - gravity constant, $\frac{\mathrm{m}}{\mathrm{s}^2}$

Figure 3 shows speed of water stream calculated from Bernoulli equation for different water pressures. Figure 4 shows influence of nozzle diameter and its distance from material being cut on water speed for pumping pressure of 3250 bar.

One of the bigger costs during abrasive water jet cutting is the cost of abrasives. Figure 5 shows mass of abrasive influencing streaming speed of water and abrasives for different nozzle diameters.

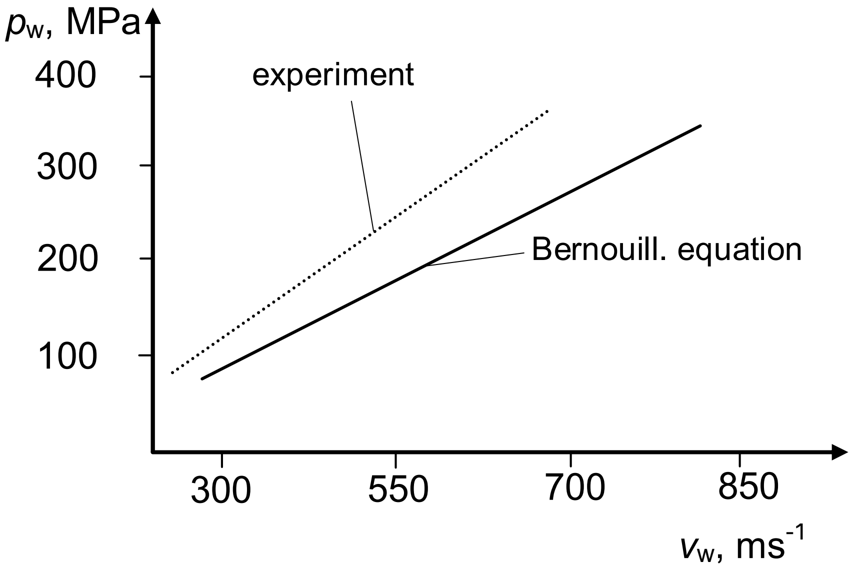


Figure 3. Water jet pressure vs. water jet speed through [2]

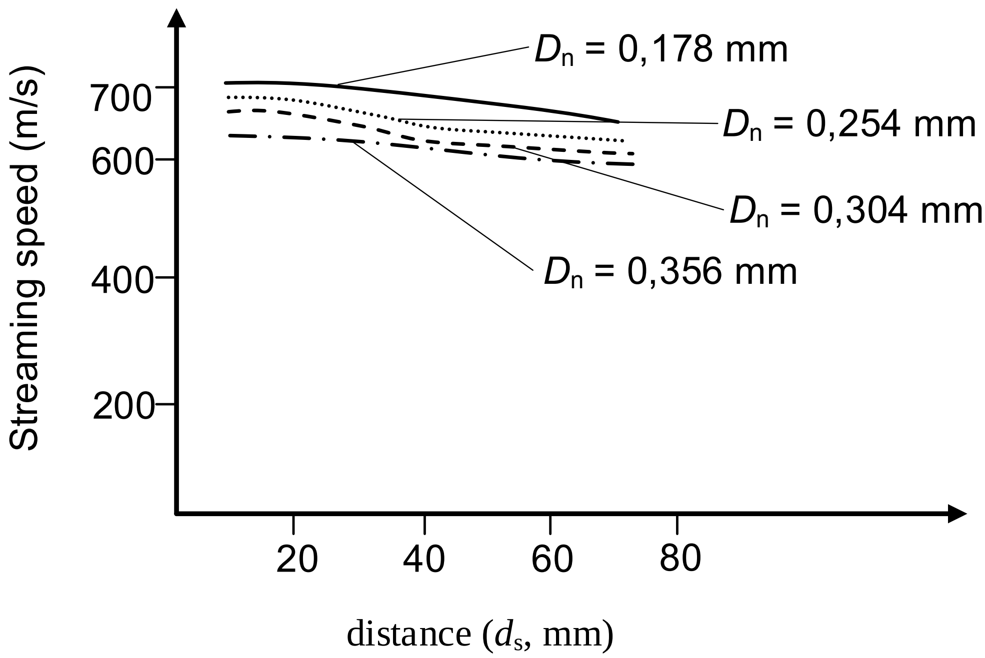


Figure 4. Estimated values of streaming speed for water pressurised at 325 Mpa [2]

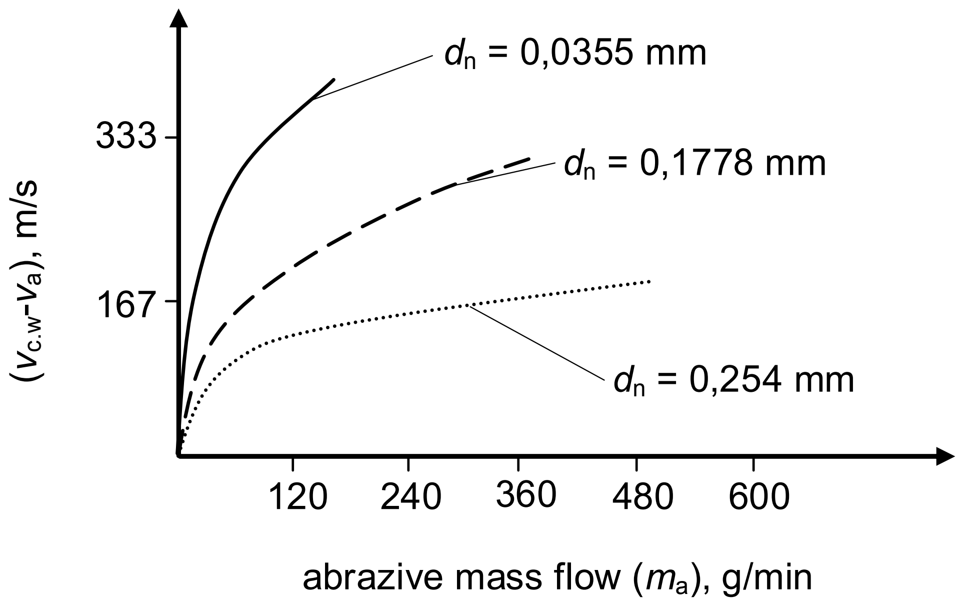


Figure 5. The influence of abrasive flow on ($v_{c.w}$-v_a) [2]

4. CONCLUSION

Cutting errors of abrasive water jet cutting were shown in this paper. At the beginning of paper difference between water jet and abrasive water jet was pointed out. Advantages of abrasive jet cutting were shown, but also the problems with nozzle life, errors on bottom surface of material.

An observation on cutting accuracy and tolerances obtained on machines of this technology and tolerances influencing factors are discussed.

Beside mentioned, the possible defects, failures and deformations with causes of their appearing are commented. Especial causes of cut tighten are discussed. The influencing factors on cutting speed and measuring procedure of abrasive water jet by Laser Transient Anemometer-LTA are explained. Mixing nozzle and relationship between convenient nozzle and spiral nozzle type are simply explained.

Also, advantages and disadvantages of cutting by abrasive jet according to other applied processes are specified.

5. REFERENCES

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[3] http://www.omax.com

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