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CONNECTION BETWEEN THE LOAD ENERGY AND THE TAPER OF CUT AT ABRASIVE WATERJET CUTTING

Accuracy of abrasive waterjet cutting mainly depends on the form of cutting gap. It is very difficult to keep in hand the taper of the gap and produce almost parallel cut surfaces. There are lot of parameters effect on the form of gap, and complex investigation of them were not published in the literature. Some results of research work carried out on an aluminium alloy related to the taper of the cutting kerf are explained in this paper, mainly from point of view of the load energy which effect to the surface of the workpiece during the abrasive waterjet cutting.

1. INTRODUCTION

Abrasive waterjet cutting has become popular the last few years because the heat of cutting does not deform the material and the cut surface is of high quality. The fact that almost every type of material (both soft and hard) may be cut by the method and that the thickness of the cut is less limited, are two of the several important advantages of the abrasive water jet technology.

When investigating the accuracy of water jet cutting, the process can be characterised by different output parameters, like surface roughness of the machined surface, geometry of cutting gap (depth, width, tapering). Cutting tests were carried out on an aluminium alloy for investigation of accuracy and quality of cutting gap. Some results of these investigations are summarised in this paper.

2. TAPER OF THE KERF AT WATERJET CUTTING

Form of cutting kerf is one of the main problems effecting on the accuracy of abrasive waterjet cutting. Form of the kerf is always very complex, cut surfaces are almost never parallel. In most cases the kerf is wider at the upper side (entering) then the lower side, where the jet goes out from the workpiece. This complex geometry is usually considered like a taper (Fig. 1.)

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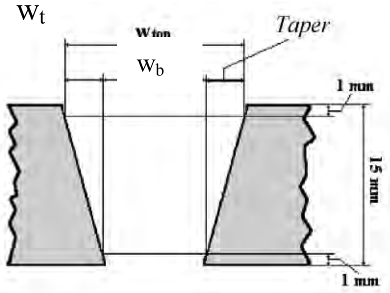
Taper of the gap causes accuracy problems at the waterjet cutting. Elimination of this error is very difficult because of the great number of effecting cutting parameters, especially if we consider the economy of the machining. Error caused by the taper can be reached the extent of 0,3 mm at cutting through a 20-25 mm thick workpiece, which is a very hard limitation of this machining method.

Taper of the cutting kerf (Fig. 1.) is usually characterised by with of the kerf at the top (upper) and at the bottom (lower) side (w_t, w_b).



w_t: top kerf width *w_b: bottom kerf width*

Figure 1 – Characteristics of the Taper of the Cutting Kerf

Fig. 8 Kerf taper

Kerf taper is normally expressed by kerf taper angle as [1]:

$$\theta = \arctan\left(\frac{w_t - w_b}{2t_n}\right) \quad (1)$$

where w_t is the top kerf width, w_b is bottom kerf width, t_n is workpiece thickness for through cuts.

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Form of cutting kerf was investigated by more authors. Öjmertz [2] establishes that form of the gap depends on lot of cutting parameters, and gives the characteristics of them, but doesn't gives any mathematical relation for express of their effects.

In an investigation of ductile materials conducted by Chung at al [3], the taper of the cut is inversely proportional to nozzle traverse speed. They also noticed, that kerf taper increases with an increase in standoff distance because the bottom kerf width has no correlation with standoff distance but the top kerf width of the kerf is directly proportional to it. In addition they found no clear relation between the kerf taper and abrasive mass flow rate.

Arola an d Ramulu [4] investigated the taper formation and influential factors using AWJ cutting graphite/epoxy composite. They noticed that kerf taper has close relation with material thickness. At cutting depth greater than 15 mm, no single parameter clearly dominates the kerf taper as it is affected by a combination of all the independent variables.

3. ENERGY LOAD AT WATERJET CUTTING

For define the load energy at first we write up the theoretical cinematic energy of the jet at the upper side, which most simply can be determined like:

$$E_m = \frac{m_a \cdot v^2}{2} \tag{2}$$

where m_a: mass of the abrasive, kg
v: speed of the particles in the jet, m/s

Real energy of the jet naturally is not equal with this value – because a lot of other factors effect on it- but clearly is proportional with this.

From the simplified Bernoulli equation for the flowing water particles speed we can get:

$$v = \sqrt{\frac{2p}{\rho}} \tag{3}$$

where: p: applied pressure, Pa
ρ: density of the water (1000 kg/m^3)

Mass of the abrasive material can be calculated:

$$m_a = \dot{m} \cdot t_a \tag{4}$$

where $\dot{m}$: abrasive mass flow rate, kg/s;
t_a: loading time, s

Considering that the loading time:

$$t_{á} = \frac{d}{f} \tag{5}$$

where d: diameter of abrasive nozzle, m
f: federate of the head, m/s

From (2)-(5) we get:

$$E_m = \frac{\dot{m} \cdot d \cdot p}{\rho \cdot f} \tag{6}$$

This theoretical value of the waterjet energy can be defined for all of applied cutting test parameters, theoretical value of the waterjet energy can be calculated.

4. CUTTING EXPERIMENTS AND RESULTS

Cutting tests were carried out for investigation of kerf taper on AlMgSi0.5 aluminium and Ti6Al4V titanium alloy (Fig. 2).

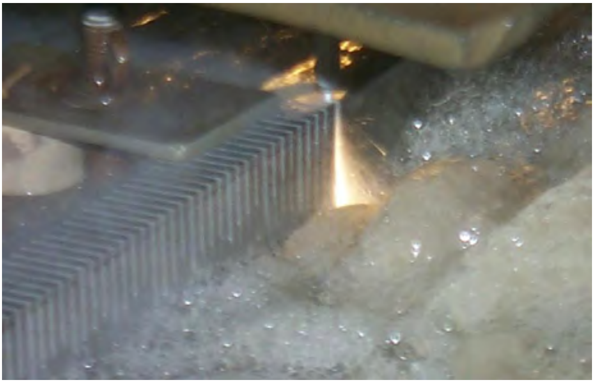

Figure 2 – Cutting Experiments on Titanium Alloy

Cutting experiments were done on a two dimensional waterjet cutting machine type INNO PUMP-36HD. Main technical data of the devices are as follows: maximum water pressure: 360 MPa; working space: 2100x1900x210 mm; positioning accuracy: ±0,15 mm; •type of abrasive federate: vibration; electric power: 30 kW; water flow rate: 1,5 l/min; control system: Messer-Griesheim

Abrasive powder was a Barton Garnet type #80 size powder, which ha 200µm average size abrasive grains.

During the cutting experiments the water pressure (p), the abrasive mass flow rate (ma) and the federate (f) were changed in different levels. Applied technological parameters were as follows:

Water pressure, MPa	350; 300; 350
Abrasive mass flow rate, g/min	200; 400
Feedrate, mm/min	50; 100; 150; 200; 250; 300

After the cutting test we measured the top (w_t) and the bottom (w_b) thickness of the cutting kerf and calculated the taper of the cut.

There are no always exact correlation between the technological parameters and the taper of the cutting kerf. Only the federate shows a good correlation to the width of the kerf (Fig. 3), but the width changes not always according to the expected tendencies.

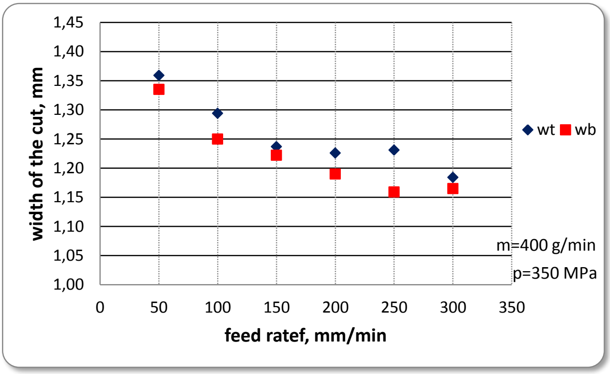

Figure 3 – Width of the Kerf in Function of the Feedrate

An interesting connection can be recognised between the load energy and the width of the kerf. Figure 4 shows the change of the top and bottom width of the kerf in function of the theoretical load energy calculated in (6).

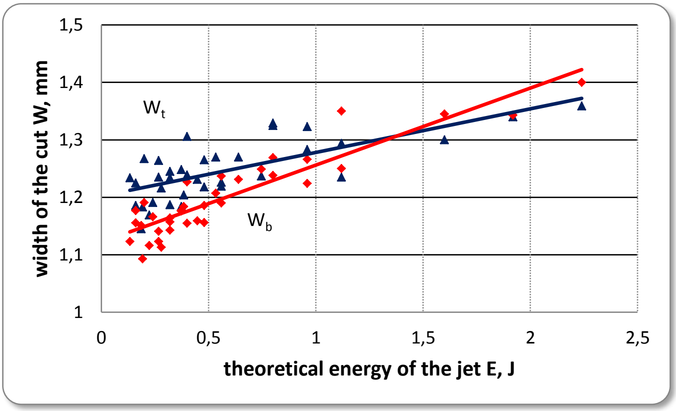

Figure 4 – Width of the Kerf in Function of the Theoretical Feedrate

On the base of the figure we can say that the width of the kerf depends on the load energy of the waterjet. Steepness at bottom (w_b) width is higher than at the top (w_t), which means that the taper of the cut decreases by increasing the loading energy of the waterjet. From the figure we can define the needed extent of the load energy for the parallel cut. Where the two lines intersect each other the width of the top and the bottom are equal, so at this value the cut is near parallel.

CONCLUSIONS

On the base of cutting experiments it can be established, that the accuracy of the cut surface is basically defined by the size and form of the cutting kerf. Cutting kerf is usually tapered, orientation of the taper is mainly depends on the quality of machined material. Extent of the taper at abrasive waterjet cutting changes in function of technological parameters. Dependency of the taper from the separated technological data does not show always clear tendencies. For the investigation of the collective effect of the different technological parameters a new energy-input approach was introduced. With help of this approach we have concluded that the form of the cutting gap can be controlled by the volume of the input energy, thus the amount of the energy input to provide near parallel cut surfaces can be determined. Parallel cut surfaces can be reached at load energy, when the top and the bottom width of the kerf are equal so parallel cut can be achieved through an appropriate choice of the technological parameters. Direction of the taper can be narrowing or expanding and at a given load energy level depends on the material.

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