HUNGARIAN JOURNAL
OF INDUSTRIAL CHEMISTRY
VESZPRÉM
Vol. 39(2) pp. 211-214 (2011)

CUTTING OF ALUMINIUM ALLOY BY ABRASIVE WATERJET

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Aluminium sheets are cut several times by abrasive waterjet cutting. The article summarizes the experimental results accomplished for determination of connection between the technological parameters and the depth of kerf. So we defined, how the depths of kerf depends on parameters (f, m, p) investigated during the research. Beyond the graphical representation of the results, we defined mathematical connection in the paper, with which the depth of kerf can be determined at given cutting parameters, before the machining process.

Keywords: abrasive waterjet, aluminium alloy, efficiency

Introduction

Ultra high-pressure abrasive water jet cutting has for the last few years become a competitor to various procedures that generate heat. The new technique has become popular 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.

Aluminium alloys are widely used in the fields of industry like aerospace and automotive industry. Abrasive waterjet cutting is one of the first operations when machining from sheet metal blanks. Investigation of depth of kerf is widely used for research of efficiency of abrasive waterjet cutting. The end-users can influence the depth of kerf mostly by the feedrate (f), the abrasive mass flow rate (m), and the water pressure.

Efficiency of the waterjet cutting

Essence of the abrasive waterjet cutting is not an abrasive machining, but a so-called solid erosion process. Solid erosion is a material loss occurred because of the collision of liquid and solid particles. The process is concentrated both in the space and in the time, so the erosion speeds up, which results machining process. During the collision of the solid particles in the liquid and the workpiece different processes can be occurred [1]: shear deformation, plastic deformation, crack formation and growth, hardening, brittle fracture and local melting of the material, *(Fig. 1)*.

Extent of erosion material removal – and with this the efficiency of the cut – depends on many parameters. Velocity and mass of particles, loading angle, rate of hardness of the workpiece and the abrasive grains, form of the particles and the material characteristics are the parameters which have significant effect on the machining process. All these defined the characteristics of the material removal.

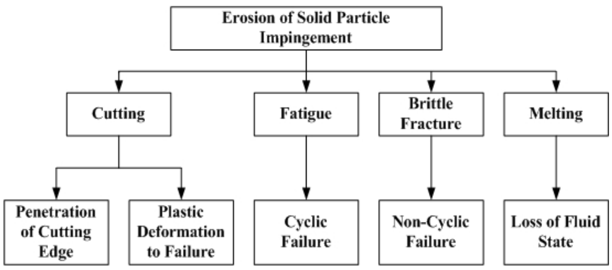


Figure 1: Material removal processes in course of solid particle erosion

When making kerfing test, we do not cut through the material, only make cuts and examine what kind of depth can be achieved with changing technological parameters. When measuring the depth of kerf *(Fig. 2)*, more measurements should be made along the cut and average of these values gives the depth of kerf (h_{max}).

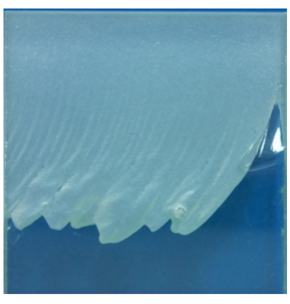


Figure 2: Kerfing in glass

From technological parameters affecting on the efficiency we investigated the effect of the feed rate, pressure, and abrasive mass flow (mass of the abrasive grains given to the waterjet during unit time). Other parameters such as nozzle diameter and diameter of focusing tube, length of focusing tube and type of abrasive material were constant. Their values were chosen on base of prior experience and professional literature.

Cutting experiments

Target of the cutting experiments was to define a method for the end users, with which the choice of technological parameters can be supported.

Tested material was AlMgSi0,5 aluminium alloy. The AlMgSi0,5 aluminium alloy widely used in different industrial fields, mainly where the strength does not has important role.

In the circle of researchers investigating the abrasive waterjet cutting is accepted that the efficiency can be graphically and easy characterised by the so called depth of kerf (*h*).

Kerfing tests *(Fig. 3)* were accomplished on the given aluminium alloy for the investigation of the efficiency.

Figure 3: Kerfing tests in AlMgSi0,5 Aluminium Alloy

The technological parameters were ranked in two groups in the course of cutting experiments, so called group of constant and changing parameters. The values of constant parameters were determined on base of facility of the machine, the changing parameters were chosen by preliminary tests. *Table 1* shows the applied parameters for the experiments.

Table 1: Parameters of Cutting Experiments in Aluminium Alloy

Constant parameters	
Material	AlMgSi0,5
Nozzle diameter	0.25 mm
Diameter of focusing tube	0.8 mm
Length of focusing tube	70 mm
Stand of Distance	2 mm
Abrasive	GARNET #80
Changing parameters	
Pressure, MPa	200; 250; 300
Abrasive mass flow, g/min	(100); 200; 400
Feedrate, mm/min	100; 300; 500; 700; (800)

Experimental results

The average of depth of kerf was measured after the cutting experiments (h).

Like it can be seen on the *Fig. 4*, increase of the feedrate results decreasing of the depth of kerf, mainly at small feedrates, the curves are hyperbolic.

Feedrate cause the most characteristic effect on the extent of the depth of kerf. Feedrate has great effect on the machining costs as well. Because of this the feedrate should be chosen always the maximal extent with which the prescribed accuracy and surface quality till can be assured.

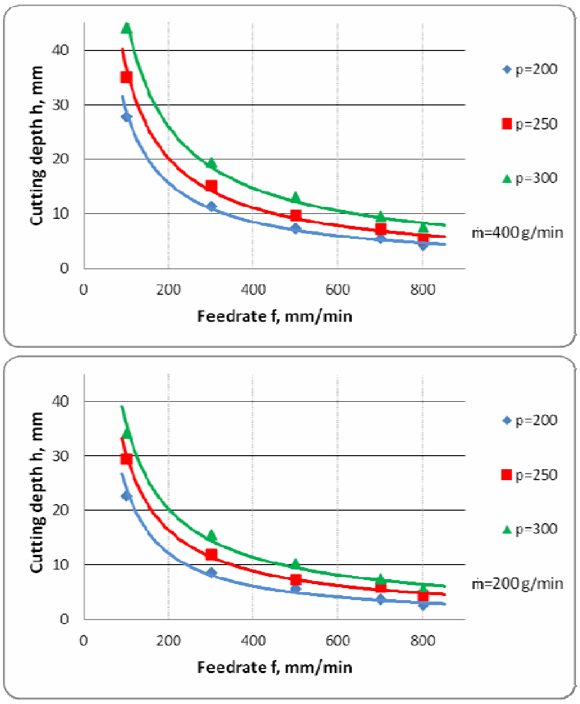


Figure 4: Effect of the feedrate on the depth of kerf at different pressures and abrasive mass flow rates, on AlMgSi0,5 aluminium alloy

On the basis of *Fig. 5* we can say that the effect of changing of the pressure is linear. Interesting to recognise that at 100 mm/min feedrate, role of change of the pressure is significant while at higher pressures (at 800 mm/min) this effect is not so significant. (inaccuracies of the curves is decreasing at higher feedrates). This phenomenon can be explained with the extent of the so called loading time. Increasing the federate the loading time is decreasing, so the higher speed of the abrasive grains, originating from the higher pressure, is not able to effect significantly on the efficiency.

Extent of the abrasive mass flow rate increases the depth of kerf *(Fig. 6)* particularly at increase of small abrasive flow rates. In the investigated interval the depth of kerf increased on double. If the mass flow rate exceeds a given value, there are too much abrasive grains will banged up from the machined surface, which results the decreasing of the depth of kerf. This can be observed only at kerfing tests, but will not appear at real cut through process.

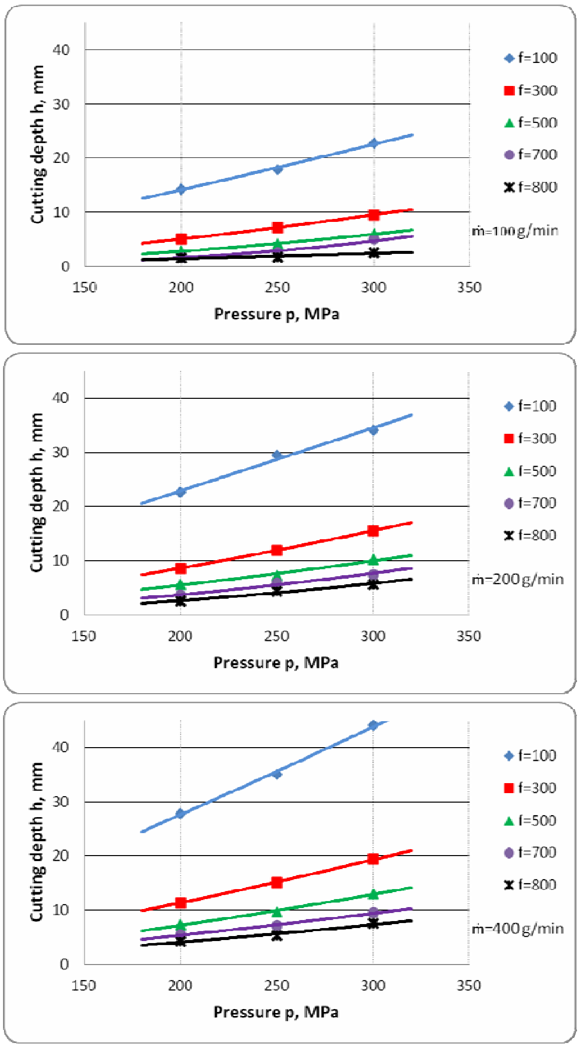
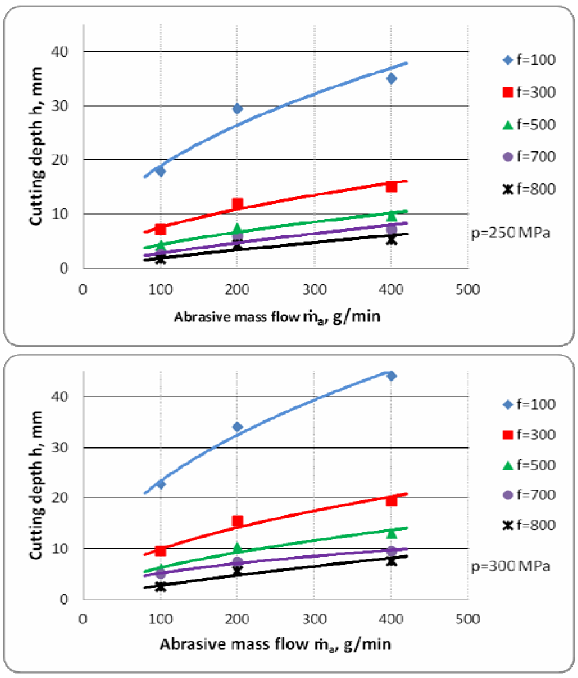


Figure 5: Effect of the pressure on the depth of kerf at different feedrates and abrasive mass flow rates, on AlMgSi0,5 aluminium alloy



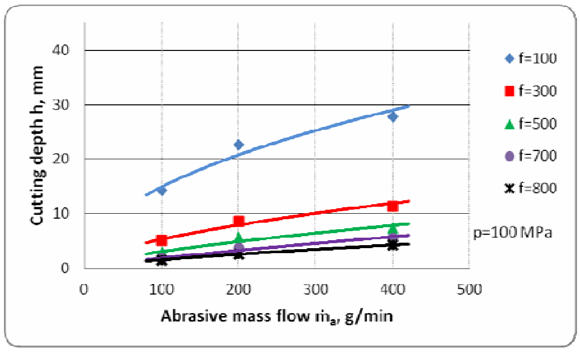


Figure 6: Effect of the abrasive mass flow rate on the depth of kerf at different feedrates and pressures, on AlMgSi0,5 aluminium alloy

Summarised effect of the parameters

Common investigation of the cutting parameters can be accomplished with help of mathematical models. In this case at optional technological parameters preliminarly can be defined the extent of the depth of kerf.

In the young history of abrasive water jets many scientists have described the effect of material removal by theoretical modelling. The models stretch from simple to complicated terms to describe the influence of different process parameters.

The most important predictive models, that have been proposed in the literature. [2] They can be subdivided as classic (Tikhomirov, Hashish, Zeng and Kim), partly empirical (Oweinah, Blickwedel, Matsui) and empirical (Chung, Kovacevic, Brandt C.) models.

On base of results of Figs 4-6, mathematical model of the cutting process can be written up as follows [3]:

$$h = A \cdot \frac{p^B \cdot \dot{m}^C}{f^D} \qquad (1)$$

where:

A − constant of the function defined by multivariable regression,

B, C, D – exponents of the function defined by multivariable regression,

h – estimated depth of cut, mm

p – pressure, MPa

$\dot{m}$ – abrasive mass flow, g/min

f – traverse feedrate, mm/min

On base of the experimental results, constants of the model and their statistical characteristics can be determined *(Table 2)*. Regression analysis of results of cutting experiments was accomplished by the MINITAB software. Applying the Monno model for the regression we have got a multivariable regression analysis, solution of which needs a linearization. [4]

Table 2: Regression constants of the Monno model

Material	A	B	C	D	R^2
AlMgSi0,5	0.046	1.270	0.706	0.947	95.30%

Extent of the defined constants is proportional to the effect intensity of the given technological parameter on the depth of kerf. With help of this correlation cut through depth can be defined at a given technological parameter combination before the real machining process. The industrial employers of the waterjet cutting do not optimise the technological parameters. Setting of those machines is happened by test cutting, in practical way/method. Special nomograms can be compiled from fulfilled results of experiments to help to user in choice of technological data. With help of the MINITAB software we are also able to generate special nomograms for end users of waterjet technology.

Conclusions

In the course of examination the feedrate, pressure and the abrasive mass flow rate was investigated from the several technological parameters effecting on the efficiency at an aluminium alloy. Based on achieved examination the following statements can be composed:

Effect of the feedrate is very characteristic. By increasing the feedrate the depth of kerf decreases decreasing acclivously mainly at slow speeds. Pressure of the water increases the depth of kerf. While at small federates the pressure has important role, at higher federates effect of the change of the pressure decreases. This can be explained with the extent of the loading time. By increasing the feedrate the loading time is decreasing, so the higher grain speed – originating from the higher pressure – cannot effect considerably on the depth of kerf.

The extent of the abrasive mass flow rate increases the depth of cut. At small abrasive mass flow rates the depth of kerf increases linearly. If the extent of the abrasive mass flow rate is higher then a given value then the depth of kerf will decrease because of the very high amount of returned grains from the cut surface. This phenomenon does not occur at cut through processes.

Machining of aluminium alloys with abrasive waterjet cutting is accomplished by solid erosion, because of this there is no need long time for the cut. This means that by increasing the pressure the abrasive grains will have high speeds and high energy, which results good material removal. Results of this phenomenon the pressure will the dominant technological parameter instead of the federate.

ACKNOWLEDGEMENT

The described work was carried out as part of the TÁMOP-4.2.1.B-10/2/KONV-2010-0001 project in the framework of the New Hungarian Development Plan. The realization of this project is supported by the European Union, co-financed by the European Social Fund.

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