USING OF WATERJET TECHNOLOGY FOR CUTTING ALUMINUM ALLOY

Tomáš Kroupa, Milan Daňa & Miroslav Zetek

This Publication has to be referred as: Kroupa, T[omas]; Dana, M[ilan] & Zetek, M[iroslav] (2017). Using of Waterjet Technology for Cutting Aluminum Alloy, Proceedings of the 28th DAAAM International Symposium, pp.0486-0492, B. Katalinic (Ed.), Published by DAAAM International, ISBN 978-3-902734-11-2, ISSN 1726-9679, Vienna, Austria
DOI: 10.2507/28th.daaam.proceedings.068

Abstract

This paper presents an analysis of the impact of AWJ Machining on the surface of Aluminium (AlMg3) parts. Samples of Aluminium are subjected to AWJ surface machining. The essence of this cutting method is the grinding of a material by using pressure from a waterjet. The jet is generated in the cutting head and terminates in the nozzle. A range of machining parameters is considered, including feed rate, cut quality, speed, and static shot. These samples are then subject to surface analysis. This analysis allows conclusions to be drawn with regard to optimal machining conditions for cut quality improvement. This experiment provided a practical verification of the theoretical assumption. The practical part with the cut samples should serve mainly to provide a better idea and easier understanding of this technology. Samples which were cut using AWJ were documented and compared. This experiment also shows that it is necessary to pay attention to ensuring the correct cutting parameters for a specific application, because even here can be seen the eternal duel between quantity versus quality.

Keywords: Unconventional machining technology; cutting material by waterjet; high pressure waterjet; abrasive material cutting

1. Introduction

Waterjet cutting technology uses the kinetic energy of a high pressure and high speed water jet for cutting material. Abrasive methods also use the kinetic energy of abrasive particles, which makes a significant difference. Material is cut by high speed erosion by abrasive particles which are concentrated into a thin ray over a small surface area. The speed of this beam is 600 – 900 m/s. It is called “hydroabrasive erosion” which is induced by a high speed hydroabrasive beam. The beam is the cutting tool in this type of technology. The particle removal of the cut material is micro-dimensional. This erosive removal goes on at practically non-elevated temperatures and therefore there is no thermal deformation around the cut. This means it is possible to cut materials that could not be divided by other methods.

Waterjet technology uses a mechanical-physical method of material removal. A very thin stream of water which has a high speed acts on the workpiece. This energy causes the beam to pass through the material, thereby machining it.

2. Methods of water jet cutting

Waterjet cutting is divided in two main methods. One method is waterjet machining, which is pure waterjet cutting. The second method is abrasive waterjet cutting (abbreviated AWJ) – which uses the addition of an abrasive medium. Both methods are similar, but they differ in the added abrasive material. In both of these methods, the cut material can be placed underwater and the device is similar. In both methods there is a minimal influence on the structure at the cut and a minimal temperature increase. The temperature increase is around 20°C and a small amount of water evaporation occurs, and sparks form around the beam. For some materials even this small increase in temperature can also mean a deterioration of the properties and possible destruction of the material.

Fig. 1. Schematic of water jet device

3. Water jet machining

Cutting with pure water without adding abrasives involves the removal of material by the mechanical effect of the waterjet, which falls on the surface of the material at a high speed and high kinetic energy over a small surface area. Due to the absence of abrasive, there are higher demands on the working fluid, which is made up of water with certain required properties. Water seems to be the best choice for the working fluid, because it offers an acceptable compromise between the required properties.

In this method the beam is created in the cutting head. Water, which is compressed, passes through a nozzle with a small hole and is transformed into a thin waterjet with high kinetic energy and high speed. This beam impacts the machined material. After impact, the beam is decelerated due to the friction between the beam and the surface of the material. The pressure can reach values up to 690 MPa. The feed rate depends on the hardness, type and thickness of the material. The feed rate can be in the range of 5 to 400 m/min. The diameter of the nozzle is about 0.3 mm, the beam has a diameter of 0.1 to 1.5 mm. The width of the cut is slightly larger than the diameter of the nozzle (about 0.3 mm). The distance of the cutting head from the material is from 2.5 to 6.35 mm but can also be 10 to 25 mm. Pure waterjet technology is suitable for cutting soft, thin, non-rigid materials. It is possible to cut various plastic materials, rubber, plasterboard, foam materials, wood and plywood. It can also be used to remove corrosion or old coatings from products and devices. But a pure waterjet is not suitable for cutting metallic materials, because there is small removal of the material and it is more advantageous to use one of the abrasive methods where efficiency is higher. [1]

4. Abrasive waterjet

AWJ stands for abrasive waterjet and it is a method with a direct supply of abrasive. This technology works on the same principle as WJM with the material removed by the effects of a thin concentrated beam acting on a very small area. Because of the abrasive, the impact from AWJ has a much more mechanical effect. In this method, the abrasive is guided from the storage, which is outside the cutting device, straight into the mixing chamber in the cutting head. The flow of the beam causes mixing under-pressure in the chamber. This under-pressure causes suction, capture and acceleration of each abrasive particle. The dosage of the abrasive in this method is about 1 to 20 kg/min. Mixing power depends on the geometry of the focusing nozzle. The working pressure is in the range of 250 to 400 MPa. The diameter of the mixed beam is higher than the pure water one because of the abrasive. [2]

The feed rate depends on the cutting material. On hard materials, the feed rate is from 10 mm/min. Hard materials include cemented carbide, titanium and cobalt. Softer materials (aluminium, glass) can be cut with speeds up to 2500 mm/min. Mixing of the waterjet and the abrasive causes a deceleration of the beam by up to half of the original value, because it causes reduced performance. The selected abrasive must have a smaller particle size than the diameter of the hole in the focusing nozzle. The size of the abrasive should be at least five times smaller than the nozzle diameter. The smaller the hole in the nozzle, the more energy of the beam can be concentrated on one place. [3]

5. The experiment

Samples which were cut using AWJ were documented and compared. Ten different conditions and modes were created, in which identical parts were cut. Only the feed rates were changed. The abrasive flow rate was not changed because the dosing is selected by software which chooses the appropriate conditions according to the thickness and type of the material to be cut. Additionally, these changes would be hard to observe on the final surface. During the experiment the feed rate, type of bullet holes and other support technologies were changed. [4]

5.1. Samples

The samples were rectangular, with dimensions 100 x 40 mm. A 12 mm thick sheet was selected as a blank. At this thickness the beam delays and surface quality changes could be easily observed. The tested material was an aluminium-magnesium alloy EN AW-5754 (AlMg3). Sheets of this material are available in a wide range of thicknesses, accessible and have good mechanical properties and good weldability. This means it is widely used in industry, especially for lightweight aluminium constructions. For this reason, EN AW-5754 was the ideal choice for the cut samples. A hole with a radius R10 was made on one edge of the sample, and on the other edge there was a bevel 10 x 45°, to observe the surface when the trajectory is changed, other than 90°. For these reasons the sample also included a series of holes with diameter 10 mm. The theoretical weight of the sample is 115 grams. [5]

The experiment took place on a device which consists of an X-Y CNC table with working dimensions 3000 x 1500 mm, with abrasive dispensers and a JETS high pressure pump. The most important parameters of this pump are shown in the following table 1.

Parameter	Value
Ambient temperature	+5°C to 35°C
Device dimensions	1690 x 1350 x 1550 mm
Weight	1800 kg
Max. outlet water pressure	4100 bar
Max. amount of water for cutting	3.8 l/min
Max. total water consumption	3.8 l/min
Inlet water pressure	3.5 – 6 bar
Max total input power	39.3 kW
Electric motor	37 kW; 1500 rpm
Hydraulic oil filling	160 l
Max. working oil pressure	215 bar
Max. working oil temperature	+52 °C

Table 1. Parameters of high pressure pump

5.2. The state of each sample

Sample 1

Parameters: static shot, medium cut quality, speed 458.84 mm/min, DRC control off and Progress Jet on (Figure 2)

Fig. 2. Sample 1

Sample 2

Parameters: direct shot, medium cut quality, speed 458.84 mm/min, DRC control off and Progress Jet on (Figure 3)

Fig. 3. Sample 2

Sample 3

Parameters: circular shot, medium cut quality, speed 458.84 mm/min, DRC control off and Progress Jet on (Figure 4)

Fig. 4. Sample 3

Sample 4

Parameters: circular shot, the roughest cut quality, speed 458.84 mm/min, DRC control off and Progress Jet on (Figure 5)

Fig. 5. Sample 4

Sample 5

Parameters: circular shot, rough cut quality, speed 731.43 mm/min, DRC control off and Progress Jet on (Figure 6)

Fig. 6. Sample 5

Sample 6

Parameters: circular shot, medium cut quality, speed 458.84 mm/min, DRC control off and Progress Jet on (Figure 7)

Fig. 7. Sample 6

Sample 7

Parameters: circular shot, smooth cut quality, speed 329.6 mm/min, DRC control off and Progress Jet on (Figure 8)

Fig. 8. Sample 7

Sample 8

Parameters: circular shot, the smoothest cut quality, speed 255 mm/min, DRC control off and Progress Jet on (Figure 9)

Fig. 9. Sample 8

Sample 9

Parameters: circular shot, smooth cut quality, speed 329.6 mm/min, DRC control on and Progress Jet on (Figure 10)

Fig. 10. Sample 9

Sample 10

Parameters: circular shot, smooth cut quality, speed 329.6 mm/min, DRC control off and Progress Jet on (Figure 11)

Fig. 11. Sample 10

5.3. Cutting parameters

Different setting properties were used for cutting the samples. Abrasive dosing settings were kept at 350 g/min for all samples. The same setting was used for the first three samples, the only difference was the type of the bullet hole: static, straight and circular. The abrasive dosing was set at 200 g/min for each bullet hole. Other samples remained with a circular bullet hole, which is the most suitable for most applications and the cutting speed was changed (samples 4 to 8). Speeds used are assigned to a particular cutting mode in the control system, the roughest, rough, medium, smooth and the smoothest. DRC controlling (radius correction) was used on Sample 9, and on sample 10 Progress Jet technology was turned off. Both the latest samples were cut in “smooth mode”. A summary is shown in the following table (Table 2.)

Sample	Bullet hole	Quality of cut	Speed rate [mm/min]	DRC controlling	Progress Jet
1	static	medium	458.84	no	yes
2	direct	medium	458.84	no	yes
3	circular	medium	458.84	no	yes
4	circular	coarsest	1102.32	no	yes
5	circular	coarse	731.43	no	yes
6	circular	medium	458.84	no	yes
7	circular	smooth	329.6	no	yes
8	circular	smoothest	255	no	yes
9	circular	smooth	329.6	yes	yes
10	circular	smooth	329.6	no	no

Table 2. Parameters of cutting

5.4. Comparison in terms of the bullet hole

Different types of bullet hole through material were used for samples 1 to 3. The cutting mode was the same for samples with medium quality and therefore all the edges look practically the same. The first sample (static shot) has a distinct edge (mesh) across the whole depth. A substantially smaller edge was created on the second sample, which is only at the bottom of the sample depth. The third sample also has a small edge, but the area around the shot was cleaner. Therefore it appeared that the best and in practice the most used type of shot for thick walled sheet metal is the circular one. [4]

For samples 4 to 8, the circular type of shot was kept. The Progress Jet function was also enabled and DRC controlling was turned off. Only the speed mode was changed on these samples. On sample 4 the setting for the fastest cut was used, and therefore the worst quality of the cut surface was achieved. Exactly the opposite setting was used on sample 8, the slowest cut with best quality. The differences between each mode are very striking. The differences with changing speed were very noticeable on the samples. At higher speeds, in the rough and roughest modes, beam delays associated with the groove phenomenon can be observed. Sample 6 was cut with the middle mode, where the beam delay was less pronounced. [6]

The assumption was confirmed that with increasing feed rate there is a delay to the waterjet beam, which is subsequently shown on the grooves on the cut edge of the material. The result is that a higher feed rate means worse surface quality. The theoretical assumption was verified experimentally. It is interesting to note that on sample 4 the speed was so high that at several places on the cutting edge, complete cutting through the material did not occur. The sample had to be released from the blank using a hammer. [7]

6. Conclusion

It has been concluded from these experiments that waterjet feed rate may have an impact on cut quality surface. After evaluating the cut samples, the circular shot appears to be the best type of shot material, because it had the least effect on the relief of its surroundings. On the contrary, the worst type of shot was static shot, where a significant edge remained throughout the whole depth of the sample. From a qualitative standpoint, direct shot is located between these shots. In practice, the most commonly used material is circular shot because of its better properties. While cutting samples on which the feed rate was changed, it could easily be seen how with increasing speed, the quality of the cut surfaces decreases. Delaying of the waterjet beam was seen at the edges, which increases with increasing feed rate. According to expectations, higher speeds mean more beam delay and, at the end, worse cut quality. This bad trait of the waterjet had a great impact on the bevel, where the cutting head did not slow down as on the sharp edges and the result is poor surface quality and incomplete cutting of the material. On the sample with the highest feed rate (sample 4), there were several uncut locations, which actually caused great problems when removing the sample from the blank. Slightly uncut parts often occur even at slower speeds, but cut samples can usually be removed without any problems or much effort from the blank. This experiment provided a practical verification of the theoretical assumption. The practical part with the cut samples should serve mainly to provide a better idea and easier understanding of this technology. This experiment also shows that it is necessary to pay attention to ensuring the correct cutting parameters for a specific application, because even here can be seen the eternal duel between quantity versus quality. [8,9]

In the future we will focus on optimizing cutting conditions, different process parameters and their influence on the process.

7. Acknowledgements

This paper is based upon work sponsored by project SGS-2016-005

8. References

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