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Experimental Study on Surface Roughness in Abrasive Water Jet Cutting

Derzija Begic-Hajdarevic[a,]*, Ahmet Cekic[a], Muhamed Mehmedovic[b], Almina Djelmic[a]

[a]*Faculty of Mechanical Engineering, University of Sarajevo, Vilsonovo setaliste 9, Sarajevo 71000, Bosnia and Herzegovina*
[b]*Faculty of Mechanical Engineering, University of Tuzla, Univerzitetska 4, Tuzla 75000, Bosnia and Herzegovina*

Abstract

In the present paper, the effects of material thickness, traverse speed and abrasive mass flow rate during abrasive water jet cutting of aluminum on surface roughness were investigated. GMT garnet was used as abrasive material with 80 mesh. Surface roughness was measured across of depth of cut. The experimental results show that traverse speed has great effect on the surface roughness at the bottom of the cut. It was also discussed the correlation between the surface roughness and other abrasive water jet cutting variables. Based on the experiments, the optimal process parameters for each material thickness were defined.

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Keywords: abrasive water jet cutting; aluminum; surface roughness; traverse speed; abrasive mass flow rate

1. Introduction

The abrasive water jet (AWJ) cutting technique is one the most rapidly improving technological methods of cutting materials. In this cutting technique, a thin, high velocity water jet accelerates abrasive particles that are directed through an abrasive water jet nozzle at the material to be cut. Advantages of abrasive water jet cutting include the ability to cut almost all materials, no thermal distortion, and high flexibility, small cutting forces and being environmentally friendly. Because of these capabilities, this cutting technique is more cost-effective than traditional and some non-traditional machining processes [1]. The mechanism and rate of material removal during AWJ cutting depends both on the type of abrasive and on a range of process parameters. In a review [2] noted that

* Corresponding author. Tel.: +387-33-729-881; fax: +387-33-653-055.
E-mail address: begic@mef.unsa.ba

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80 mesh garnet is the optimum type and size in most cases. A great deal of research has been done to improve the cutting performance and enhance the cutting capacity of AWJ cutting technique, including studies of the mechanism of the AWJ cutting process [3, 4] and modeling for process control and optimization [5, 6, 7]. Especially, kerf shape and quality in AWJ cutting of sheet material have been studied in a number of recent research works [8, 9]. The surface quality is one of the most specified customer requirements and the major indicator of surface quality on machined parts is surface roughness. The surface roughness is mainly a result of various controllable or uncontrollable process parameters and it is harder to attain and track than physical dimensions are. A considerable number of studies have researched the effects of the feed rate, standoff distance, water pressure, abrasive grain size, and other factors on the surface roughness [10, 11, 12]. Thus, it is necessary to have a deeper knowledge about the optimum operation conditions, which will permit us to assure a good surface roughness. The aim of this study was examined the effects of abrasive water jet variables such as traverse speed, abrasive mass flow and material thickness on surface roughness in abrasive water jet cutting of aluminum. The varied surface roughness across the depth of cut was also examined.

2. Experimental procedure

The experiments were conducted on a NC 3015 EB abrasive water jet cutting system with a KMT Streamline ™ SL-V 50 ultra-high pressure pump capable of providing maximum water pressure of 413.7 MPa. Cutting was performed on aluminum plates of different thicknesses 15 mm and 30 mm. The constant process parameters are shown in table 1.

Table 1. Constant parameters and their values.

Constant parameters	Orifice diameter	Focusing tube diameter	Water jet pressure	Abrasive type	Abrasive size (grit no)
Value	0.20 mm	0.762 mm	350 MPa	GMT garnet	80 mesh

Two variable process parameters (traverse speed and abrasive mass flow rate) have been selected for the present study, table 2.

Table 2. Variable parameters and their values.

Variable parameters	Traverse speed mm/min	Abrasive mass flow rate g/min
Material thickness 15 mm	77, 100, 139, 250, 350	100, 130, 200, 250, 320
Material thickness 30 mm	37, 49, 69, 109, 130	240, 285, 320, 350, 390

The controlled parameter has been the surface roughness. Surface roughness (with a cutoff of 0.8 mm) on the cut surface was measured in terms of the average roughness *Ra*, using the Surf-Test Mitutoyo stylus instrument; see Fig.1. The measurement of surface roughness was performed in the Laboratory for Cutting Technologies-LaTOOS, Faculty of Mechanical Engineering in Sarajevo. Surface roughness (R*a*) measurements are made at different zones of the cut surface as shown in Fig.2.


a)


b)

Fig. 1. (a) the samples with linear cuts prepared for the measurement of surface roughness; b) the measurement of surface roughness.

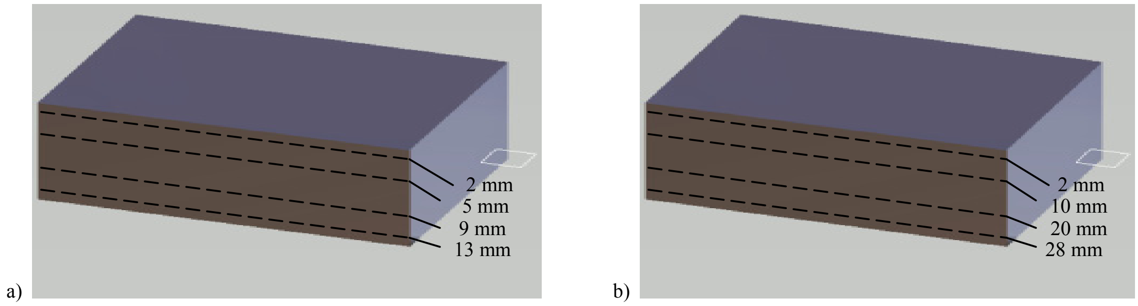

Fig. 2. Schematic view of the cut surface where roughness was measured: a) sample of 15 mm; b) sample of 30 mm thickness.

3. Results and discussions

In this section, the effect of the process parameters such as: traverse speed, abrasive mass flow rate and material thickness on the surface roughness during AWJ cutting of aluminum plate was analyzed.

3.1. The effect of the traverse speed on the surface roughness

The effect of the traverse speed on the surface roughness during AWJ cutting of a 15 mm thick aluminum was shown in Fig.3. Experiments were made at the constant value of abrasive mass flow rate, *m*= 320 g/min.

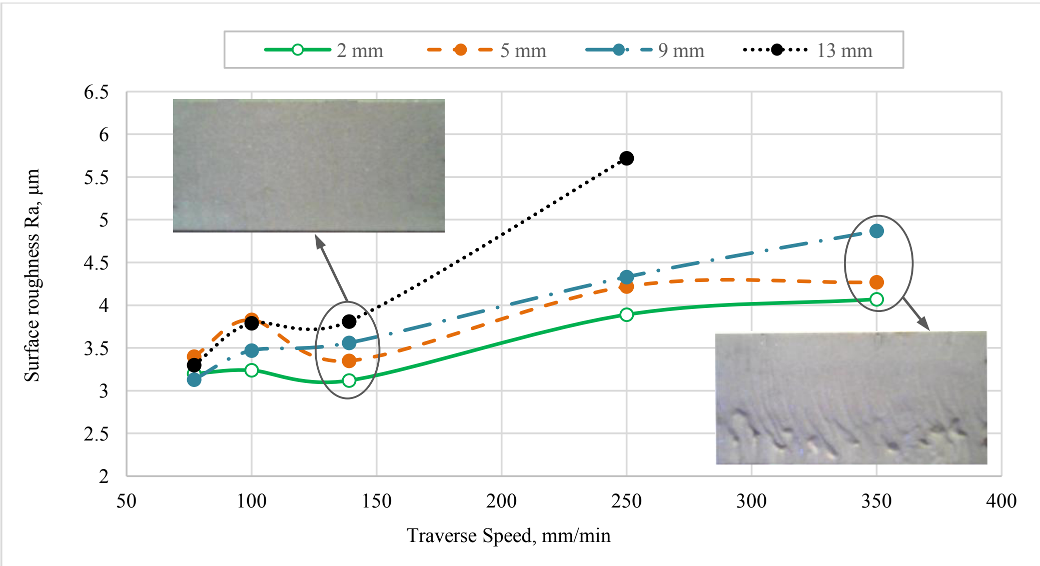

Fig. 3. The effect of traverse speed on the surface roughness on different zones of the cut surface – 15 mm thickness.

It can be seen that the surface roughness increases by increasing of traverse speed. Also, it can be observed that the roughness *Ra* slightly changes through the whole depth of cut surface at low traverse speeds e.g. at a speed of 139 m/min and less. The surface roughness increases by increasing of the depth of cut surface, especially at the higher traverse speeds. The cut sample was considered unacceptable at a speed of 350 mm/min, because the roughness has been unable to measure at the depth of 13 mm from the entry jet, see Fig.3.

The effect of the traverse speed on the surface roughness in AWJ cutting of a 30 mm thick aluminum plate was shown in Fig.4. Experiments were made at the constant value of abrasive mass flow rate, *m* = 390 g/min.

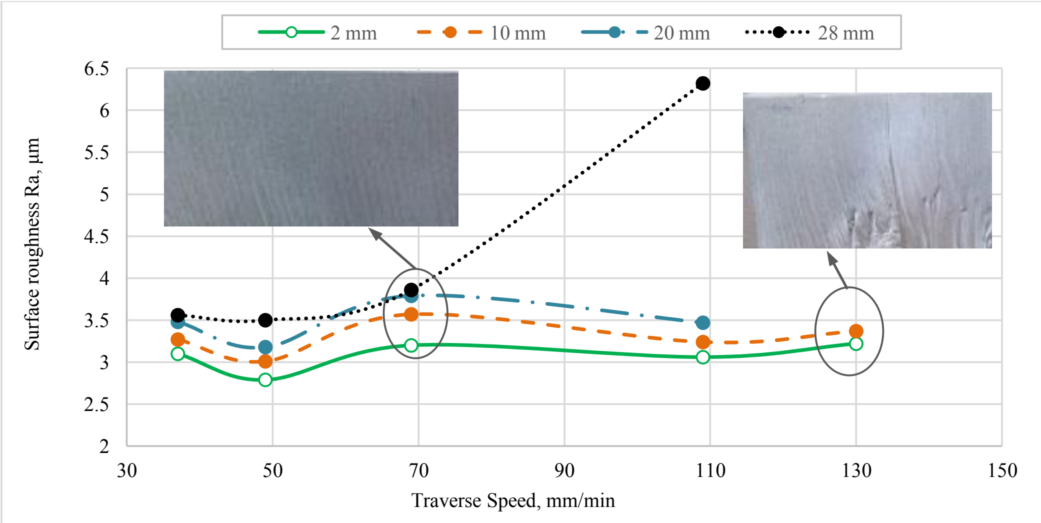

Fig. 4. The effect of traverse speed on the surface roughness on different zones of the cut surface – 30 mm thickness.

It can be seen that the roughness *Ra*, which was measured at the depth of 2 mm and 10 mm from the entry jet, slightly changes by increasing of traverse speed. But the roughness *Ra*, which measured at the depth of 28 mm from the entry jet, rapidly increased at the traverse speeds higher than 69 mm/min. So, the cut sample was considered unacceptable at a speed of 130 mm/min, because the roughness has been unable to measure at the depth of 20 mm and 30 mm from the entry jet, see Fig.4.

Based on the above results, the optimal traverse speed was 139 mm/min and 69 mm/min during AWJ cutting of aluminum plate of 15 mm and 30 mm thickness, respectively.

3.2. The effect of the abrasive mass flow rate on the surface roughness

The effect of the abrasive mass flow rate on surface roughness during AWJ cutting of a 15 mm thick aluminum was shown in Fig. 5. Experiments were made at the constant traverse speed, v = 77 mm/min.

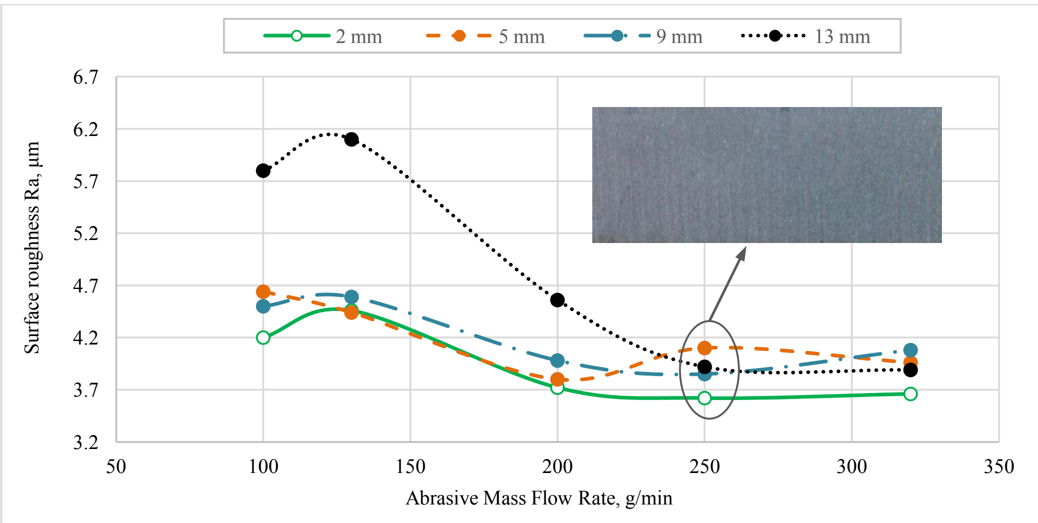

Fig. 5. The effect of abrasive mass flow rate on the surface roughness on different zones of the cut surface – 15 mm thickness.

The effect of the abrasive mass flow rate on surface roughness during AWJ cutting of a 30 mm thick aluminum was shown in Fig. 6. Experiments were made at the constant traverse speed, v = 37 mm/min.

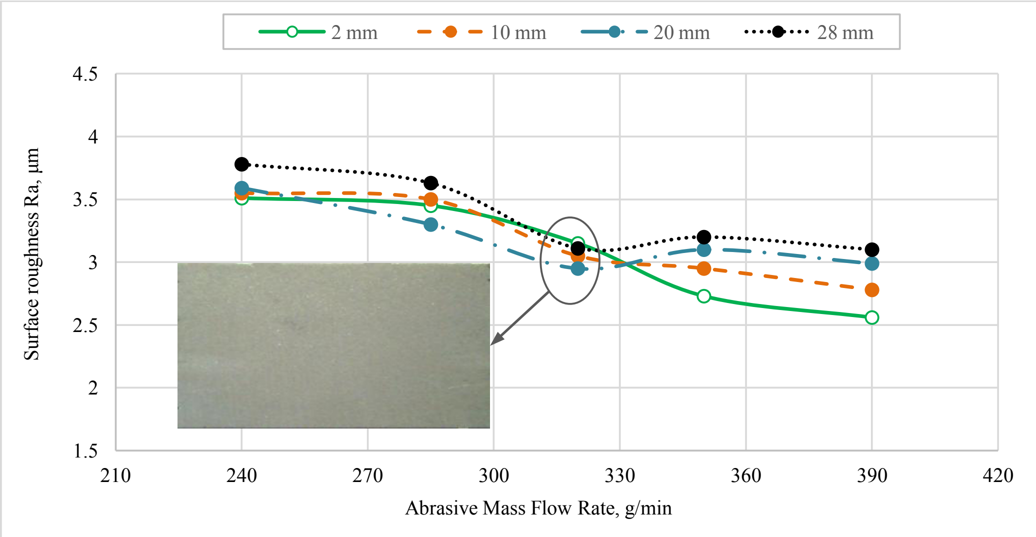

Fig. 6. The effect of abrasive mass flow rate on the surface roughness on different zones of the cut surface – 30 mm thickness.

As seen in Figs. 5 and 6, the surface roughness decreases by increasing of abrasive mass flow rate. Under the analyzed conditions, the effect of abrasive mass flow rate depends of the cut's depth. As shown in Fig. 5, the effect of abrasive mass flow rate on the surface roughness increases as the cut's depth increases.

Based on the above results, the optimal abrasive mass flow rate was 250 g/min and 320 g/min during AWJ cutting of aluminum plate of 15 mm and 30 mm thickness, respectively.

3.3. The effect of the material thickness on the surface roughness

The effect of material thickness on the surface roughness during AWJ cutting of aluminum plate of 15 mm and 30 mm thickness was shown in Fig. 7. Experiments were made at the constant abrasive mass flow rate, 320 g/min (for thickness of 15 mm) and 390 g/min (for thickness of 30 mm).

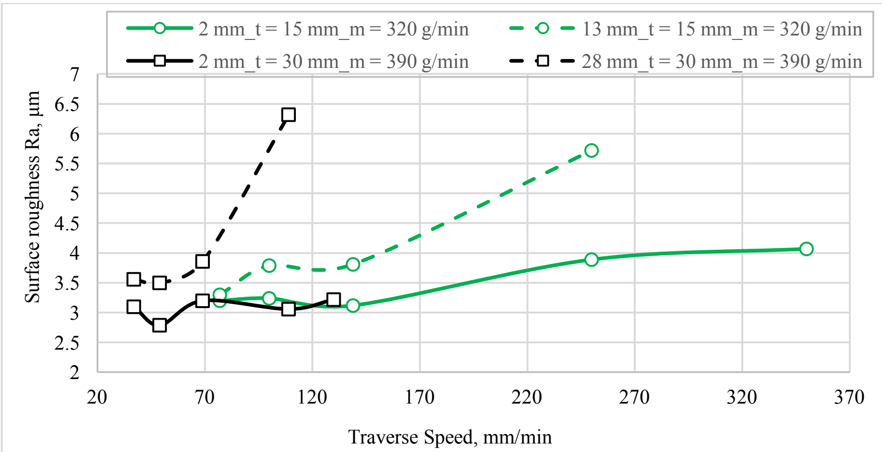

Fig. 7. The effect of material thickness on the surface roughness at the different traverse speeds.

An increase in material thickness caused an increase in surface roughness, especially on the bottom of cut. The smallest change in the surface roughness was occurred at the lower traverse speeds. The traverse speed has no great effect on the surface roughness at the beginning of cut. By increasing the depth of cut and the traverse speed, the surface roughness increases. As shown in Fig.7, the traverse speed strongly depends of the material thickness, by increasing the material thickness, the traverse speed decreases.

Conclusion

Due of comprehensive experimental research, detailed theoretical investigations and performed analysis, it is possible extract followed conclusions:

- The surface being cut by the abrasive water jet was characterized by two types of surface texture. The first texture was located at the beginning of the cut and was characterized by the smooth surface. The second texture was located at the bottom of the cut and was characterized by the rough surface.
- The optimal solution is the choice of medium traverse speed with which can be achieved higher productivity with acceptable surface roughness.
- Also, in order to reduce processing costs, the abrasive mass flow rate may be reduced in relation to the manufacturer's recommended value, because the surface roughness slightly changes by increasing the abrasive mass flow rate.

In the future work, more detailed discussions for the effect of different process parameters such as water jet pressure, stand-off distance, abrasive grain size, and type material will be considered.

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