




AKADÉMIAI KIADÓ

# Some characteristics of surfaces machined with abrasive waterjet turning

Krisztina Kun-Bodnár\*  and Zsolt Maros

Institute of Manufacturing Science, Faculty of Mechanical Engineering and Informatics, University of Miskolc, Egyetemváros, H-3515 Miskolc, Hungary

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## ABSTRACT

This paper presents an experimental study of abrasive waterjet turning of an extrusion aluminum alloy (AlMg0,7Si). The aim of the paper is to determine differences of two methods from the point of view of machined surface quality and the depth of penetration, i.e., the diameter of the parts after the turning process. During the experiments, the traverse speed of the cutting head and the rotation of the turned parts were changed, other parameters, like pressure of the water, abrasive mass flow rate were kept constant. Diameter and some surface roughness parameters of the test parts were measured after the machining. On the base of experimental results, advantages, and disadvantages of two methods are explained in the paper.

## KEYWORDS

abrasive waterjet turning, surface roughness, tangential method, radial method, aluminum alloy

## 1. INTRODUCTION

Abrasive waterjet machining is a non-traditional technology applied widely nowadays in industry. Abrasive waterjet turning is one of these technologies, which gives the possibility to machine cylindrical, conical, and other rotationally symmetric parts made of hardly machined materials.

At waterjet turning the workpiece rotates with speed  $v_{fc}$ , while the jet moves linear in axial direction, with speed  $v_{fa}$ . At tangential method, the jet placed in a given radius, at radial method above the workpiece in the symmetric axis of it (Fig. 1). The resulting depth of cut ( $a_p$ ) is the result of several factors in both cases [1, 2].

Material removal is caused by a mixture of abrasive dust, water and air in the jet. When machining with a waterjet, the cutting force is very small, which allows cutting long and relatively small diameter parts [3, 4]. The process is suitable for cutting brittle and difficult-to-cut materials such as glass, ceramics, composites or various super or titanium alloys [5–7].

Performance of different machining technologies usually is made by optimization methods [8]. Quality of the process frequently is characterized by the machined surface [9]. In this research work the waterjet turning process is investigated on base of extent of the material removal and the different parameters of machined surface roughness. Experimental research was carried out for determine the main characteristics of radial and tangential waterjet turning.

## 2. EXPERIMENTAL CONDITIONS AND TEST EQUIPMENT

In the experiment, the surface of AlMg0.7Si aluminum alloy was machined by abrasive water jet turning.

\*Corresponding author.

E-mail: krisztina.bodnar@uni-miskolc.hu



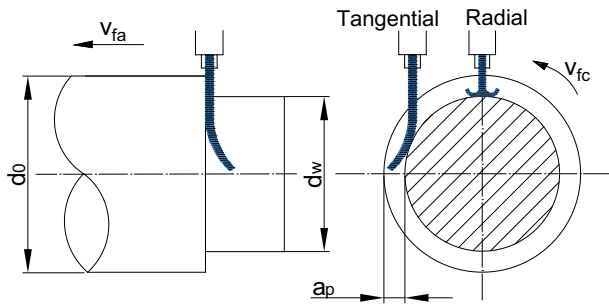


Fig. 1. Tangential and radial abrasive waterjet turning

## 2.1. The rotating device and the machine-tool

To perform the experiments, a rotating device (Fig. 2) was developed, mounted on a CORTINA DS2600 type, two-dimensional abrasive waterjet cutting machine.

The rotating device [10] has been designed and constructed in accordance with the following criteria:

- Machining can be performed on the machine tool and the machine must provide the feed;
- The mounting of the device must be stable;
- Device ensures that the workpiece fixturing and rotation;
- Electronic components must be safety protected from water;
- Number of rotations of the workpiece must be adjustable.

The equipment consists of three main units: drive, water protection structure and support structure.

## 2.2. Measurement of roughness of machined surfaces

Roughness of the machined surfaces was measured in one of the laboratories of the Institute of Manufacturing Sciences at University of Miskolc on an AltiSurf 520 surface topographical measuring machine (Fig. 3).

The device has three type of measuring head mechanical (needle), confocal and laser. The measurements of machined surfaces were accomplished with laser head because of the relative high surface roughness of machined surfaces.

The profile roughness measurements were carried out in axial direction, on 3 locations on each test specimen, at both tangential and also radial waterjet turning. The positions on the mantle were marked about  $120^\circ$  apart. The spatial roughness measurements were carried out on one  $8 \times 4$  mm area, on the middle of the cylindrical surfaces.

After machining, profile (2D) and spatial (3D) roughness characteristics were also determined to characterize the roughness of the surfaces.

To visually inspect the machined surfaces, photographs of the surfaces were taken with a ZEISS Stereo Discovery.V8 microscope.

## 2.3. Experimental settings

During the cutting experiments, the water pressure was kept constant and the feed speed and workpiece speed were varied. The setting data is shown in Table 1.



Fig. 2. Rotating device for abrasive waterjet turning  
(Source: K. Kun-Bodnár)

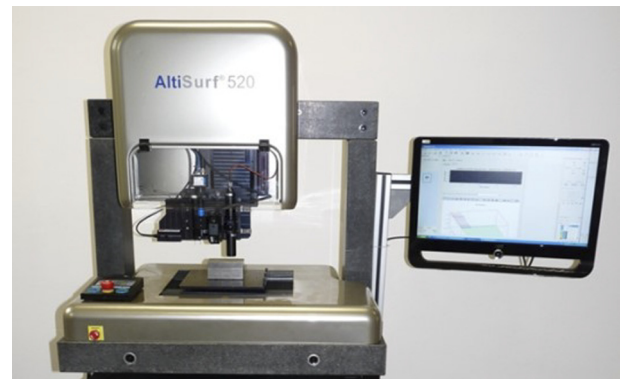


Fig. 3. AltiSurf 520 surface topographical measuring machine  
(Source: photo by Zs. Maros)

Waterjet turning experiments were performed on the same specimens with radial and tangential adjustment with the same technological parameters (Fig. 4).

Thanks to the surfaces placed on the same specimen, the two types of turning methods became visually comparable.

Describe the applied methods, experiments and procedures in sufficient detail to allow other authors to reproduce the result. This part may have subheadings.

## 3. EXPERIMENTAL RESULTS

The comparison of the different methods was made partly based on the thickness of the removed layer and partly based on the roughness of the machined surfaces.

The thickness of the removed material layer was determined with measurement of the diameter of the specimens before and after the waterjet turning. The change in the thickness of the removed layer is shown in Fig. 5.

It can be seen in Fig. 5 that the radial turning can remove a thicker layer of material in all cases under the same technological parameters, i.e., it is more efficient in terms of material removal. It can also be seen that increasing the feed rate, the thickness of the deposited layer decreases.

After the experiment more parameters of surface roughness characteristics were measured. In the industry most widely used parameter is the average surface roughness ( $R_a$ ).



Table 1. Parameters of experimental settings









| Test specimen                                                                       | Method         | $m_a$<br>$\text{g min}^{-1}$ | $p$<br>bar | $n$<br>$\text{1 min}^{-1}$ | $v_f$<br>$\text{mm min}^{-1}$ | Test specimen size |             |
|-------------------------------------------------------------------------------------|----------------|------------------------------|------------|----------------------------|-------------------------------|--------------------|-------------|
|                                                                                     |                |                              |            |                            |                               | diameter [mm]      | length [mm] |
|    | 1.(tangential) | 400                          | 3,000      | 200                        | 10                            | 48                 | 30.2        |
|                                                                                     | 2.(radial)     | 400                          | 3,000      | 200                        | 10                            | 48                 | 30.2        |
|    | 1.(tangential) | 400                          | 3,000      | 200                        | 5                             | 47.8               | 30.2        |
|                                                                                     | 2.(radial)     | 400                          | 3,000      | 200                        | 5                             | 47.8               | 30.2        |
|    | 1.(tangential) | 400                          | 3,000      | 200                        | 2                             | 47.9               | 30.2        |
|                                                                                     | 2.(radial)     | 400                          | 3,000      | 200                        | 2                             | 47.9               | 30.2        |
|    | 1.(tangential) | 400                          | 3,000      | 100                        | 15                            | 47.8               | 30.1        |
|                                                                                     | 2.(radial)     | 400                          | 3,000      | 100                        | 15                            | 47.8               | 30.1        |
|    | 1.(tangential) | 400                          | 3,000      | 100                        | 10                            | 47.8               | 30.2        |
|                                                                                     | 2.(radial)     | 400                          | 3,000      | 100                        | 10                            | 47.8               | 30.2        |
|    | 1.(tangential) | 400                          | 3,000      | 300                        | 5                             | 48                 | 30.2        |
|                                                                                     | 2.(radial)     | 400                          | 3,000      | 300                        | 5                             | 48                 | 30.2        |
|  | 1.(tangential) | 400                          | 3,000      | 300                        | 3                             | 48                 | 30.2        |
|                                                                                     | 2.(radial)     | 400                          | 3,000      | 300                        | 3                             | 48                 | 30.2        |
|  | 1.(tangential) | 400                          | 3,000      | 300                        | 2                             | 48                 | 30.2        |
|                                                                                     | 2.(radial)     | 400                          | 3,000      | 300                        | 2                             | 48                 | 30.2        |



Fig. 4. Surfaces machined by radial (left) and tangential (right) waterjet turning (feed speed  $2 \text{ mm min}^{-1}$ , number of rotation  $2001 \text{ min}^{-1}$ ) (photo by K. Kun-Bodnár)

Figure 6 shows the change in the average surface roughness ( $R_a$ ) from the method and the traverse feed speed at the same experimental settings as Fig. 5.

Based on Fig. 6, it can be seen, that the machined surfaces with more favorable roughness can be obtained by

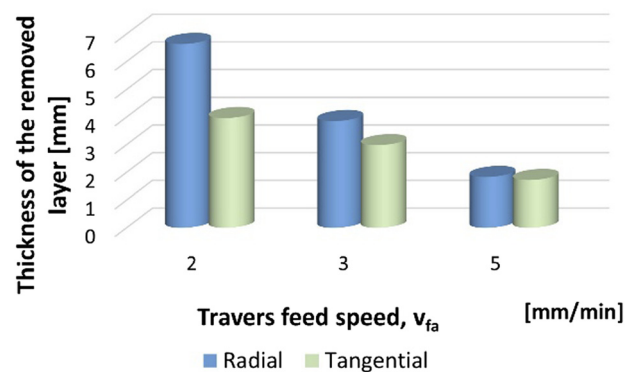


Fig. 5. Thickness of deposited material layer for radial and tangential waterjet turning as a function of feed speed (motor rotation  $3001 \text{ min}^{-1}$ , abrasive mass flow rate  $400 \text{ g min}^{-1}$ )

tangential water jet turning. The change in roughness as a function of feed is not clear.

Similar characteristic can be observed in the change of total height ( $R_t$ ) of roughness profile (Fig. 7).

In Fig. 7 the values of radial cut are always higher than the tangential, especially at lower feed speed. Total height parameter decreases at radial turning in function off feed

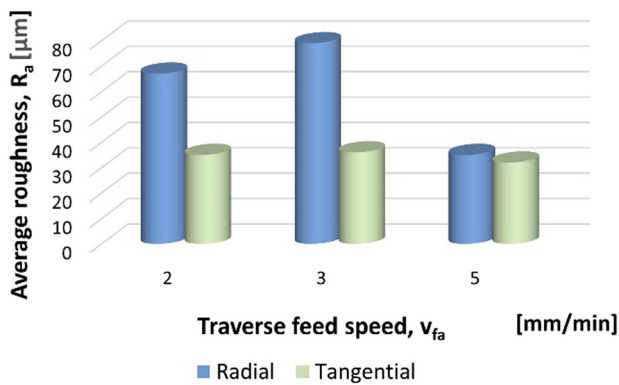


Fig. 6. Change in average roughness as a function of feed speed (motor rotation  $300 \text{ l min}^{-1}$ , abrasive mass flow rate  $400 \text{ g min}^{-1}$ ) with radial and tangential water jet turning

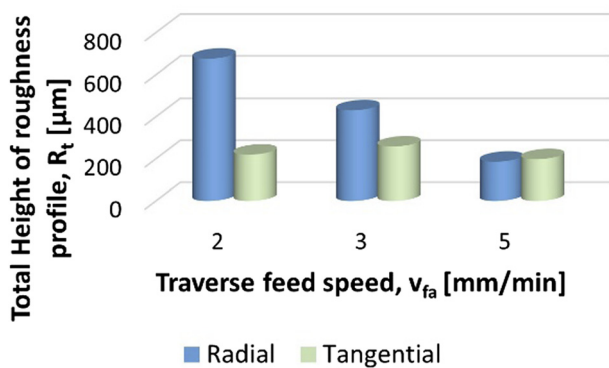


Fig. 7. Change in total height of roughness as a function of feed speed (motor rotation  $300 \text{ l min}^{-1}$ , abrasive mass flow rate  $400 \text{ g min}^{-1}$ ) with radial and tangential water jet turning

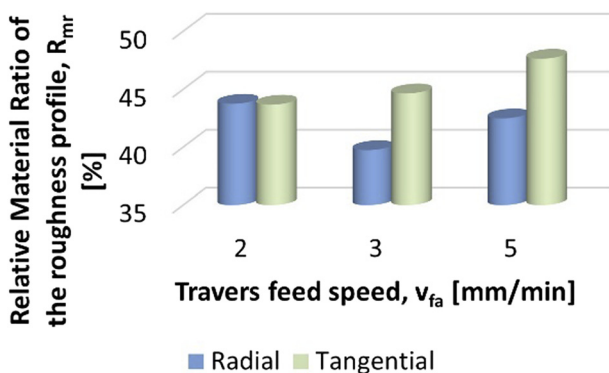


Fig. 8. Change in relative material ratio as a function of feed speed (motor rotation  $300 \text{ l min}^{-1}$ , abrasive mass flow rate  $400 \text{ g min}^{-1}$ ) with radial and tangential water jet turning

speed. At tangential turning characteristic tendency cannot be established. Extent of total height roughness is about 5–6 times higher than average roughness of the same surfaces. This phenomenon is similar to mechanical turning, where this ratio is about 5.

The relative material ratio ( $R_{mr}$ ) of the machined surfaces was also measured after the cutting. This surface

roughness parameter is a functional parameter and characteristics the extent of the bearing surface. As higher is the material ratio as better slip and wear properties has the machined surface.

In Fig. 8 can be seen that material ratio of the surfaces is higher at tangential waterjet turning then at radial one. At tangential turning the values increase in function of feed speed. This mean that better functional surfaces can be reached at higher feed speed. The radial turning does not show clear trend.

## 4. CONCLUSIONS

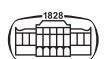
Summarizing the results, based on the experiments comparing the two types of water jet turning, the following conclusions can be made:

- For machining with the same technological parameters, a higher material removal efficiency can be achieved with the radial process;
- The thickness of the removed material layer clearly decreases with increasing feed rate;
- For tangential process, the set depth of cut is not equal to the thickness of the layer removed;
- The average roughness of the surface is smaller in the case of the tangential process and it does not show a clear change as a function of the feed speed;
- Total height parameter decreases at radial turning in function of feed speed. At tangential turning characteristic tendency cannot be established;
- Radial process is better from the point of relative material ratio parameter of the machined surfaces, higher feed speed results in better sliding and wear properties;
- Tangential waterjet turning is easier to handle process comparing to the radial waterjet turning.

In summary, abrasive water jet turning can be used to machine materials well, but ensuring the required size is not accurate for finishing. With tangential abrasive water jet turning, better surface quality can be achieved, with radial process; greater material removal efficiency can be achieved. Further studies are needed to clarify the ongoing processes.

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