J. BARALIĆ, B. NEDIĆ, V. MARUŠIĆ

Focusing Tube Wear and Quality of the Machined Surface of the Abrasive Water Jet Machining

The wear of the focusing tube is a very important feature of the abrasive water jet machining. Of all rejected focusing tubes, 85% are worn. Similary, the age of focusing tube influences the cut geometry and quality of machined surface. With regard to the stated, wearing of the focusing tube is subject of this paper. Focusing tube outlet diameter was measured as well as its influence on the surface quality.

Keywords: focusing nozzle, wear, surface quality

INTRODUCTION

Continuous development of high pressure water jet machining was initiated in the first decade of the twentieth century.

In the USA, this machining method was first applied in gold mines. Approximately at the same time, this method was introduced in Russian coal mines.

In early sixties of the past century, O. Imanaka of the Tokio University began to apply pure water in industrial machining. The idea was postulated on the damages observed on the plane fuselage induced by raindrop beat.

Towards the end of the sixties of the past century, R. Franz of the Michigen University began the study of wood cutting by high speed water jet. It was the method of detecting of steam leaking that inspired him to initiate the study.

The above brought about the application of the first commercial usage of water jet. Mc Cartney Manufacturing Company was the first to produce water jet for machining which was installed in Alto Boxboard in 1972. Since then, high pressure water jet has been primarily used for machining of soft materials, such as wood and leather. Pure high pressure water jet was not only used for machining of materials known to be brittle, such as granite and stone, but also in tough ones, such as titanium.

Towards the end of the sixties of the past century, R. Franz of the Michigen University began the study of wood cutting by high speed water jet. It was the method of detecting of steam leaking that inspired him to initiate the study.

The above brought about the application of the first commercial usage of water jet. Mc Cartney Manufacturing Company was the first to produce water jet for machining which was installed in Alto Boxboard in 1972. Since then, high pressure water jet has been primarily used for machining of soft materials, such as wood and leather. Pure high pressure water jet was not only used for machining of materials known to be brittle, such as granite and stone, but also in tough ones, such as titanium.

Further investigations led to the discovery of abrasive water jet in 1980 and its first commercial application in 1983. Adding the abrasive to water jet significantly widened the scope of materials to be treated in this manner. In addition, higher machining speed was thus ensured along with greater accuracy of processing and higher quality of the machined surface.

Abrasive water jet machining is an unconventional method of machining. It has been industrially applied for a long period of time. The most common operations performed by this method of machining are cutting, polishing, cleaning, etc. In all stated options, the machining mechnism is based on erosion. The fact that no major rise in temperature occurrs at machining in the processing zone is a huge advantage of this machining method.

[1] *MSc Jelena Baralić, Assistant Trainee, Technical Faculty Čačak, University of Kragujevac, Serbia*
[2] *Prof. dr Bogdan Nedić, Faculty of Mechanical Engineering, Kragujevac, University of Kragujevac, Serbia*
[3] *Prof. dr Vlatko Marušić, Faculty of Mechanical Engineering, University of Osijek, Croatia*

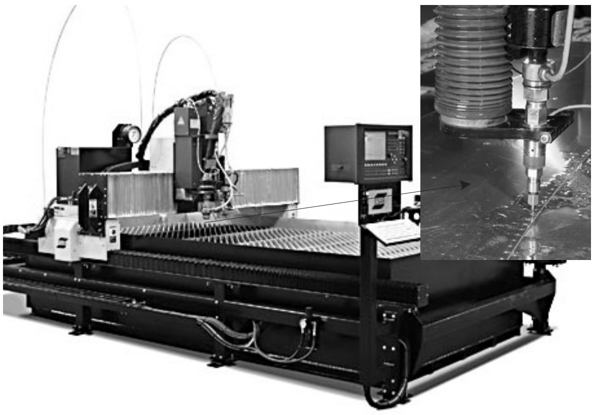

Figure 1. Abrasive water jet instalation, and a nozzle

The machining by abrasive water jet is particularly suitable for the machining of brittle materials (glass, ceramics, stone, etc.) and composite materials as well. An abrasive water jet instalation is presented in Fig. 1.

Modern abrasive water jet instalations are water assisted at a pressure exceeding 4000 bar, whereby water jet reaches even up to 900 m/s. The scheme presenting machining with non-abrasive water jet is shown in Fig. 2a, whereas abrasive-assisted water jet is shown in Fig. 2 b.

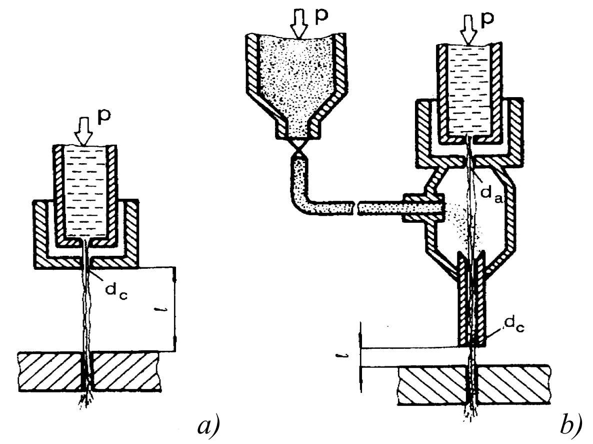

Figure 2. Scheme of machining with non-abrasive water jet (a) and abrasive-assisted water jet (b).

FOCUSING TUBE WEAR

Figure 3 shows the working part of an abrasive water jet installation is most commonly called water jet head or nozzle.

The inlet water entering the water jet head (nozzle), most commonly at 300÷4000 bar pressure, passes through jewel. The diameter of the jewel entry ranges from 0,18÷0,4 mm. Extremely small diameter of the nozzle ensures very high water speed, amounting up to 900 m/s. The jet subsequently arrives at the mixing chamber the diameter and length of which are usually 6 mm and 10 mm respectively.

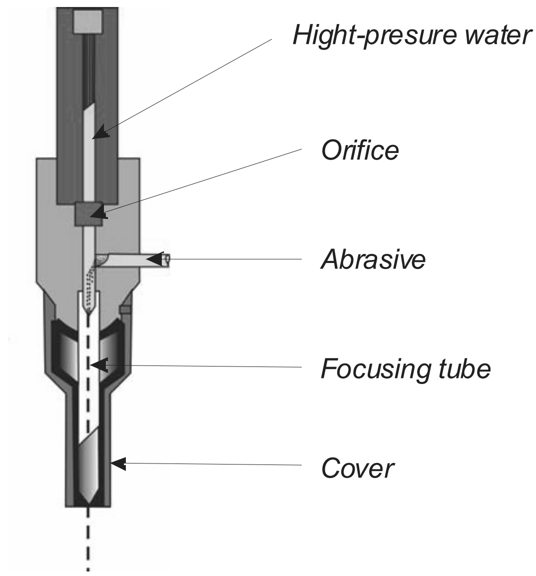

Figure 3. Water jet head (nozzle), scheme

Owing to the Venturio effect vacuum occurs, sufficient to absorb a particular amount of abrasive dependent on the abrasive nozzle diameter. Water jet speeds up the abrasive particles accompanying them through a long cylindrical focusing tube. Water and abrasive mix exits the focusing tube in the form of a coherent jet providing the machining. Figure 4 presents the process.

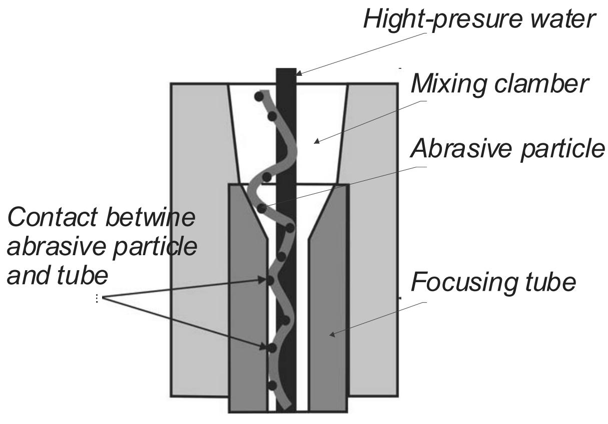

Figure 4. Scheme of the mixing process

Focusing tube is usually made of tungsten carbide. Its inner diameter and length range from 0.8 to 1.6 mm and 50 to 80 mm respectively. It is tungsten carabide that is used owing to its high resistance to to abrasive wear.

The term 'wear' is used to manifest a number of issues, such as:

- Tube weight loss
- The incidence of wear patterns along the inner surface
- Change of the outlet geometry
- Exit diameter increase

The initial wear of the focusing tube is easiest identified by monitoring of the tube weight loss. The tube is measured before the beginning of the process as well as over the period of machining. Weight loss is induced by the erosion of the inner wall of the focusing tube which also brings about the incidence of wear patterns along the inner surface of the tube. Excessive usage of the focusing tube causes changes in the exit geometry, i.e. the occurence of the opening exccentricity. The exccentricity is defined by the ratio between the smallest and the biggest size at the exit.

The most common method for monitoring of the state of the focusing tube is monitoring of the exit diameter. A number of authors have found linear relationship between exit diameter and time.

Different parameters of the machining , i.e. size of abrasive particles, focusing tube length govern the increase in the exit diamter.

EXPERIMENTAL INVESTIGATIONS

This paper presents the study of the focusing tube wear and its effect on the quality of the machined surface, i.e. roughness of the machined surface. The ROCTEC©100 focusing tube has been used. Through the investigation, the focusing tube was being exposed to identical conditions. Working water pressure and abrasive flow were 3500 bar and 306g/min abrasive being garnet mash#80. The data provided by the producer suggest 120 hours of exploitation life of the tubes.

t, min	0	855	1545	2345	3195
d_f, mm	1.02	1.055	1.109	1.152	1.318

The diameter of the tube outlet has been major parameter of wearing of the focusing tube. The diameter was being checked at specific intervals.

In this paper, the focusing tube wear was investigated by the half of the exploitation life of the tube. Ispitivanje habanja cevi za usmeravanje mlaza je u ovom radu vršeno do polovine radnog veka cevi. The ROCTEC©100 focusing tube has been investigated. The followoing parameter values at which the focusing tube was being exposed over the study were constant, i.e.

- working pressure p = 3500bar
- abrasive flow Qa = 306 g/min
- abrasive type – garnet, MASH#80

The diameter of the focusing tube outlet was measured at the beginning of the process using a new tube. It was subsequently checked over 10- to 15-hour interval.

Measuring of the diameter of the tube outlet was concurrent with cutting of samples made of different materials so as to monitor the effect of the focusing tube wear on roughness of the machined surface. These sample materials were used:

1. X6CrNi18-10KT (Č 4580): Rm=630 MPa; $R_{p0.2}$=205Mpa
2. marble, dry state compressing solidity β_{max}=109Mpa, density 2.71 g/cm^3
3. clyrate, PMMA, density 1.150 to 1.190 kg/m^3

All samples were treated at idential cutting speed (V=120mm/min). Ra was used as major roughness parameter.

Ra parameter was checked at five and three spots along the sample length and heights respectively, as shown in Fig. 5.

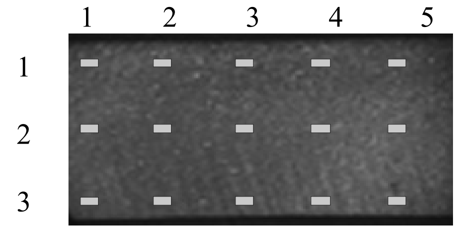

Figure 5 Checking spots along the machined sample surface

According to the study results presented in diagram has been created showing to what extent focusing tube wear depends on cutting time

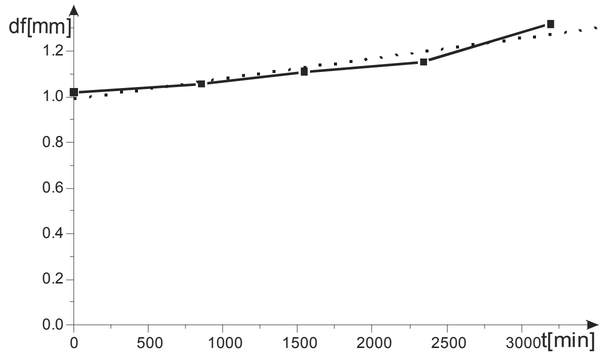

Figure 6. Change of the diameter of the tube outlet, d_f being in the function of cutting time

As shown in the figure, the longer duration of cutting the wider diameter of the focusing tube outlet. As previously noted, a number of authors firmly suggest linear correlation between these parameters, therefore the broken line in the figure stands for linear function which, by the smallest quadrate method, best provides approximate values of the correlation obtained by the study.

Roughness was checked at PERTHOMETER S5P

Figure 7 presents roughness change, i.e change in Ra function of cutting time for X6CrNi18-10KT

(Č4580) which has been monitored at three different heights of the machined sample.

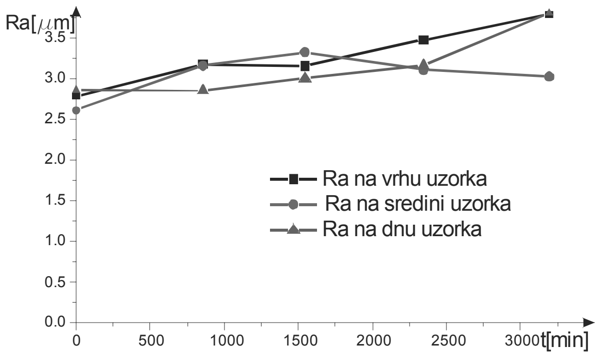

Figure 7 Change in Ra function of cutting time for X6CrNi18-10KT (Č4580)

1. at the top
2. at middle section
3. at the bottom

Figures 8 and 9 show changes in *Ra* roughness parameter functioning as cutting time at three heights of the sample, for marble and clyrate.

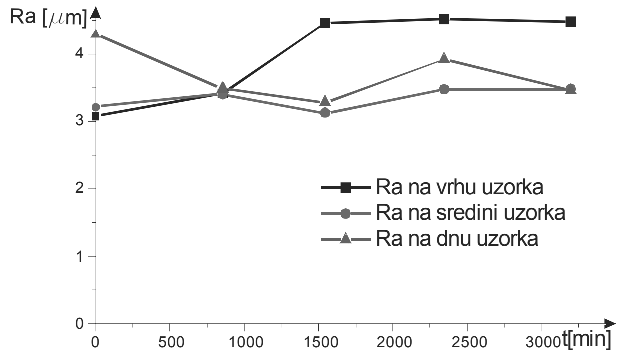

Figure 8. Change in Ra function of cutting time for marble

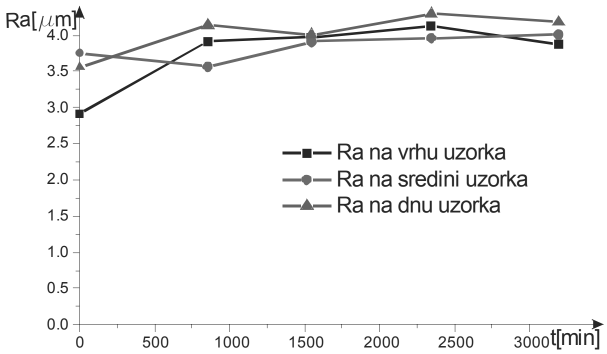

Figure 9 Change in Ra function of cutting time for clyrate

All diagrams infer rise in the *Ra* roughness parameter with cutting time. This clearly suggests firm correlation between roughness of the machined surface and focusing tube wearing.

CONCLUSION

This paper presents the results of the investigation of the correlation between cutting time, change in the diameter of the focusing tube outlet and quality of the machined surface.

It has been suggested that longer duration of cutting induces the increase in the diameter of the focusing tube outlet, this correlation being almost linear. Further experiments are required in order to obtain more accurate correlation of the stated parameters.

Similarly, close relationship between quality of the machined surface and cutting time is also obvious. The longer the working time of the tube the more pronounced roughness of the machined surface for the stated working parameters. This correlation is quite obvious in iron and clyrate, whereas serious irregularities have been evidenced in marble. Roughness at the bottom of the sample occurred regularly as compared to the one at the top of the sample.

In brittle materials, such as marble, pronounced wavering has been evidenced, which may further explain why the results of marble investigation show irregularities. Further investigations are required so as to check and explain this claim.

REFERENCES

[1.] D. Arola, M. Ramulu: Material removal in abrasive waterjet machining of metals: Surface integrity and texture, *Wear*, Vol. 210 (1997), pp. 50-58.

[2.] E. Lemma, L. Chen, E. Siores and J. Wang: Optimising the AWJ cutting process of ductile materials using nozzle oscillation technique, Int. J. Mach. Tools Manuf. Vol. 42/7 (2002), pp. 781-789.

[3.] M. Hashish: A modeling study of metal cutting with abrasive water jets, J. Eng. Mater. Technol., Vol. 106 (1984), pp. 88-100.

[4.] Hunt D.C., Burnham C.D., Kim T.J., Surface Finish Characterization in Machining Advanced Ceramics by Abrasive Water jet, University of Rhode Island, Kingston, 2003.

[5.] Momber A.W., Kovacevic R., Principles of Abrasive Water jet Machining, Springer, London, 1998.

[6.] KENNAMETAL, catalogs