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THE TRAVERSE SPEED INFLUENCE ON SURFACE ROUGHNESS IN ABRASIVE WATERJET CUTTING APPLICATIONS

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Abstract: *Abrasive water-jet (AWJ) machining is an unconventional method of machining. In all stated options, the machining mechanism is based on erosion of the material uppon which the jet hits. The fact that no major rise in temperature occurs at machining in the processing zone is a huge advantage of this machining method. This study is focused on the surface roughness of abrasive water-jet (AWJ) cut surfaces. In the study is explained the influence of traverse speed on the machined surface roughness. In the presented study, Č4580 was machined under varying traverse speeds of 10 to 70 mm/min by abrasive water-jet machining. After machining, the machined surfaces were examined and surface roughness was measured. The experimental results indicate that the traverse speed is a parameter with significant influence on the surface roughness. It was observed that the surface roughness increases with increasing traverse speed.*

Keywords: *Abrasive water-jet, surface, roughness, traverse speed, Č4580*

1. INTRODUCTION

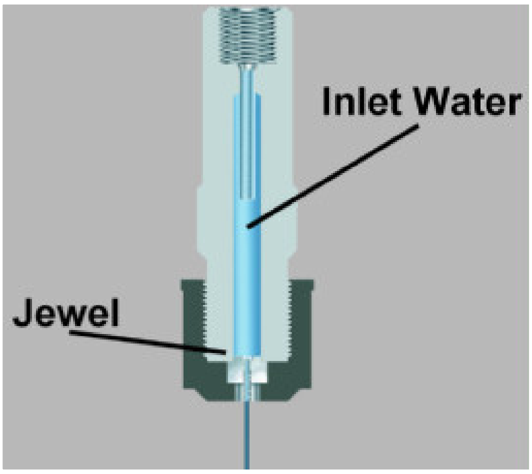
The faster the development of new production technologies is, the greater challenges face the scientists. Requirements regarding accuracy of shapes and measurements of the final products are becoming more demanding. Furtermore, specific requirements concerning complexity of the shape of the product have recently been set. Therefore, unconventional machining methods have been more frequently applied in modern production. Nowadays, the increasing number of reaserches are conducted in the field of unconventional machining methods with the purpose of obtaining the fastest, the cheapest and high quality machining method.

When selecting the appropriate technology, the most significant features that affect the final decision are the quality of the machined surface and the time required for the design of a product. The quality of the machined surface, during the cutting process, is a complex concept which covers changes of characteristics of material, structure, and size of the defect layer, roughness of the machined surface and geometrical characteristics of the cut. Due to the fact that sometimes it is impossible to satisfy all these criteria in practice, some of them are neglected depending on the required result. The quality of the cutting process can be evaluated through measuring certain characteristics such as roughness of the machined surface, through satisfying demands of tolerance, parallelism of the cut sides and their normality to the base surface [1].

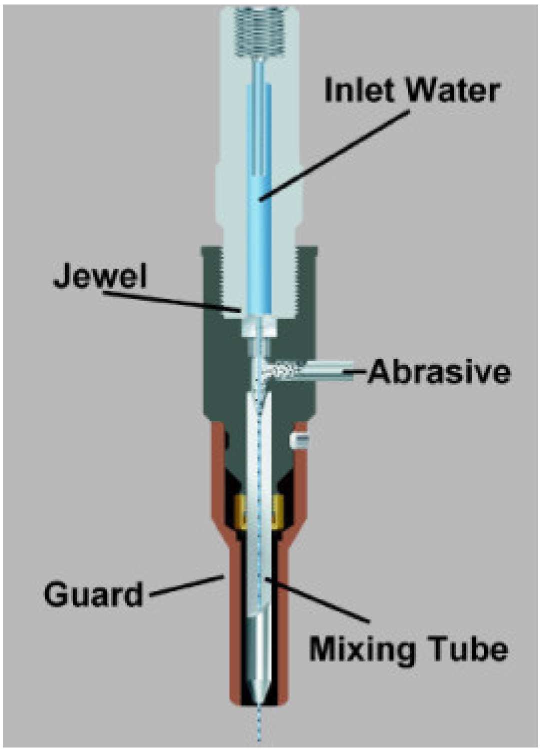
2. ABRASIVE WATER-JET MACHINING

Abrasive water-jet machining is one of the newest unconventional machining methods. This type of machining has significantly changed metal machining industry. Abrasive water-jet makes possible the accurate designing of the parts with complex contours and high quality machined surface in a very short period of time. No temperature increase in the cutting zone, the possibility of complex contours design and no occurrence of residual stress in the cutting zone characterize this machining. Thus, the abrasive water-jet machining has been significantly developed recently. AWJ machining is most frequently applied in profile cutting of various slab-like materials. This machining method is very convenient for the design of different types of materials. Furthermore, abrasive water-jet machining is economic and eco-friendly.

Continuous development of high pressure water-jet machining was initiated in the first half of the twentieth century. However the addition of abrasive material to the water-jet extended the range of machinable materials significantly. Higher machining speed and accuracy as well as higher quality of the machined surface were also achieved.



a)



b)

Figure 1. Schematic diagram of water-jet machining without abrasive material a) and with abrasive material b) [2]

The most frequent operations carried out through this type of machining are: cutting, polishing of surfaces, cleaning of surfaces, etc.. In the stated options, the machining mechanism is based on erosion. A particular advantage of this machining method is the fact that no significant temperature increase occurs in the machining zone. A schematic diagram of water-jet machining without abrasive is shown in Figure 1. a), whereas abrasive water-jet machining is displayed in Figure 1 b). Modern installations for abrasive water-jet machining function if the water pressure is above 5000 bar, and the water-jet reaches the speed of 1400 m/s.

Abrasive water-jet machining is based on the erosion process as the main mechanism of the workpiece material removal. Workpiece material removal is a continuous process beginning with the impact between the abrasive particle and the material, which causes the removal of a very small amount of the workpiece material. The number of the abrasive particles striking the workpiece material in one second amounts to ten thousand [3].

3. SURFACE MACHINED WITH ABRASIVE WATER-JET

The biggest problem during abrasive water-jet machining is unevenness of the machined surface quality. The unevenness is manifested in different values of the machined surface roughness parameters, deviations of the machined surface from the vertical plane and the occurrence of the surface waviness and curved lines (striae) on the machined surface. All the above mentioned issues greatly affect limitation on the application of the abrasive water-jet machining. Nevertheless, no study that offers complex estimation of the surface topography depending on the parameters of machining mode has been conducted.

The basic characteristic of the surface machined with abrasive water-jet is the duality of the surface. The upper zone of the surface machined with abrasive water-jet (jet entery side) shows significantly less roughness compared to the lower zone of the machined surface. The end of the upper surface zone is usually called smooth cutting zone. The occurence of waveness, curved lines, and increasing roughness of the machined surface, is more frequent beyond the smooth cutting zone. During the penetration of abrasive water-jet through material, kinetic energy of abrasive particles decreases, which causes retardation of the cutting front of the jet. Y_{ret} (Figure 2). Retardation of the cutting front of the abrasive water-jet and loss of its energy bring about the occurence of curved lines on the machined surface and the change of quality of the machined surface, i.e. the change of the roughness of the machined surface for different depths of the cut.

Roughness of the machined surface, i.e. its change depending on the depth of cut is the most important parameter for the estimation of the effect of certain machining parameters on the quality of the machined surface. Many authors state that the analysis of surface topography provides key informaton about the mechanism of abrasive water-jet machining. Figure 2. shows the characteristic appearance of the surface machined with abrasive water-jet and the quality change in machined surface depending on the depth of cut.

Ra parameter is the main parameter that defines the quality of the machined surface. Figure 3 shows the change of this parameter and the change of the parameters Rq and Rz.

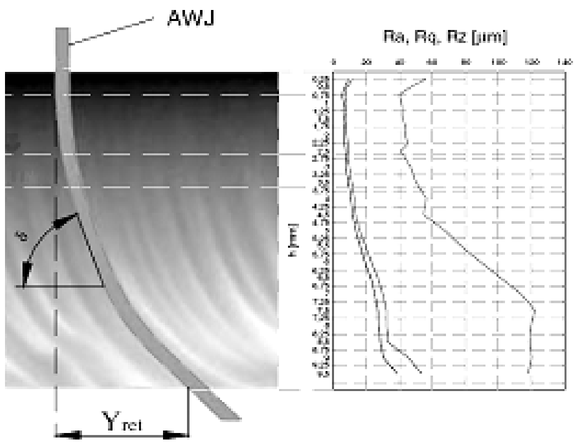


Figure 2. Change in appearance and quality of surface machined by abrasive water-jet for different depth of cut [4]

The quality of the machined surface is affected by cutting modes during abrasive water-jet machining, such as operative pressure, the amount of abrasive, traverse speed, etc.. This machining is also characterised by the change of width of the cut depending on the machining parameters. All the irregularities affect the limited application of this type of machining in industry. Figure 3. shows the appearance of the cut, i.e. the change of the width and conicality of the cut depending on the change of traverse speed.

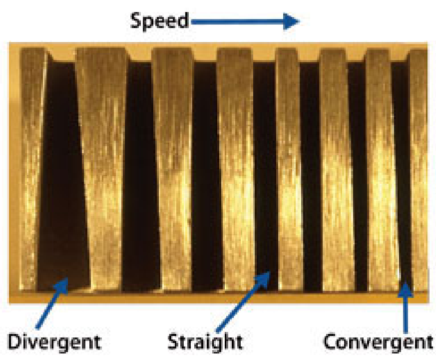


Figure 3. Appearance of cut for different traverse speed [2]

As far as the quality of the machined surface is concerned, five distinctive classification groups can be discerned (Figure 4.). The machined surface which is at Q1 quality level is characteristic for rough cutting of workpieces at high traverse speed. An additional force is necessary to bring about the separation of the cut workpieces. The machined surface requires further machining.

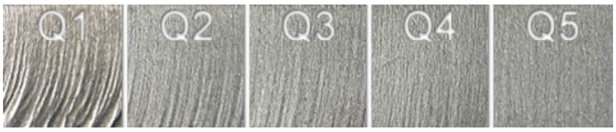


Figure 4. Five characteristics of machined surface quality [2]

Q2 machined surface quality is obtained during the cutting process of workpiece (the parts are completely separated), and in most cases further machining is necessary. Q3 machined surface quality is more demanding than the previous two. In order to reach high quality of the machined surface it is necessary to adjust traverse speed, operating pressure, abrasive water jet speed and the amount of the abrasive material. Such machining modes enable the production of the certain fixed parts, i.e. further machining is not necessary depending on their purpose. Q4 machined surface quality is higher than Q3 machined surface quality. At this quality level, many parts can be designed without additional machining. Q5 machined surface quality is very high and it is achieved in high accuracy parts but at very low traverse speeds wherein the machining time is not the criterion for the selection of the cutting mode. The width of the cut is constant at both upper and lower parts of the machined surface.

4. TRAVERSE SPEED EFFECT ON THE QUALITY OF THE MACHINED SURFACE

All irregularities of the machined surface, obtained either by standard or unconventional machining method (laser, plasma, abrasive water-jet) are characteristics of the machined surface and they are accurately standardized. The subject of the research is roughness of the surface machined with abrasive water-jet and the effect of traverse speed on the machined surface.

The quality of the surface machined by the abrasive water-jet can be influenced by system operational process parameters such as water-jet pressure, abrasive flow rate, standoff distance, depth of cut, angle of cutting, and traverse speed [5]. The effect of certain parameters is different. Majority of authors agree that the greatest impact on the surface quality have traverse speed, operating pressure and amount of abrasive material.

Traverse speed of the jet has a strong effect on the surface finish of the workpiece and material removal rate [6]. Therefore, it is necessary to identify the connection between the quality of the machined surface and traverse speed.

Figure 5. shows the typical relation between traverse speed and machined surface roughness. With an increase of traverse speed, roughness will increase significantly. The diagram refers to the analysis conducted on aluminium [7]. The diagram displays the relation between traverse speed and roughness: at low traverse speed no significant difference in roughness of the machined surface occurs with the change in depth of cut, whereas at higher traverse speed (around 2mm/s), the diffrence becomes obvious.

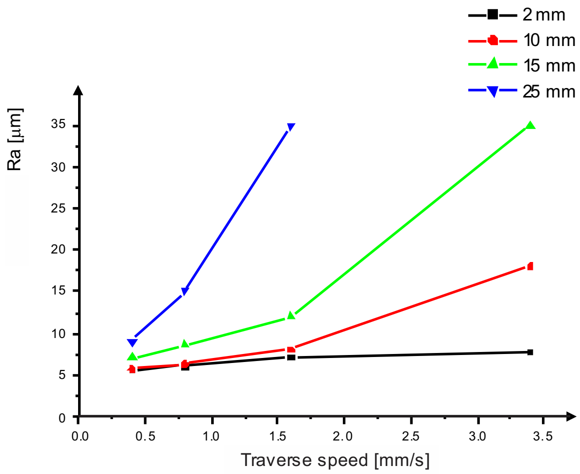


Figure 5. Effect of traverse speed on quality of machined surface [7]

In this paper we analyzed the effect of traverse speed on the quality of the machined surface of Č 4580 (AISI 304) stainless steel. Figure 6. shows the appearance of the machined sample surfaces Č 4580 (30 mm thick), with different traverse speed. The Figure indicates that during machining process at traverse speed of 10 mm/min, no significant difference in quality of the machined surface occurs. Neither surface waviness nor curved lines occur. During machining process, with higher traverse speeds, the difference in quality of the machined surface is more distinct and it varies depending on depth of the cut. In order to observe the difference carefully, we carried out the measurement of roughness of the surfaces machined at different traverse speeds (from 10mm/min to 70mm/min). The recommended traverse speed for Č4580 steel (thickness 30mm and Q3 medium machining quality) is 35 mm/min. The values of the remaining parameters of the machining process were kept constant:

- Operating pressure p = 4130bar
- Abrasive flow Qa = 400 g/min
- Abrasive type – garnet, MASH#80

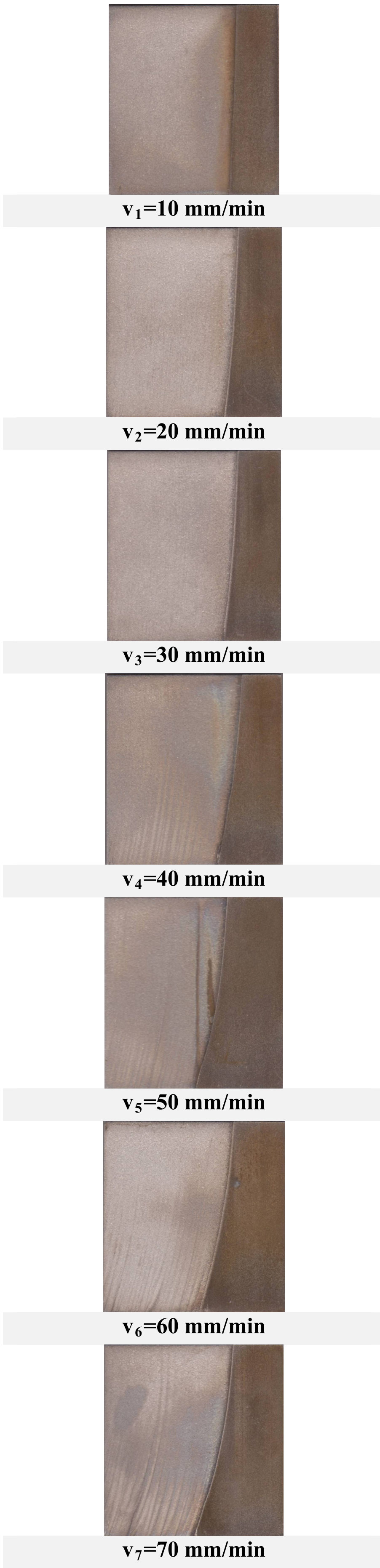


Figure 6. Appearance of machined surface depending on traverse speed

Ra parameter has been considered the most significant for the estimation of machined surface quality. The values of Ra parameter have been measured for different cutting conditions – for 6 different depths of cut: 2,5mm, 7,5mm, 12,5mm, 17,5mm, 22,5mm and 27,5mm, and for 5 different lenghts. Then the mean values of Ra parameter were calculated at the appropriate depth of cut. On the surface machined with traverse speed of 70mm/min, it was impossible to measure Ra. Table 1. displays thus obtained results.

Table 1. Measured values of Ra parameter [µm]

Traverse speed [mm/min]		Depth of measurement [mm]					
		2.5	7.5	12.5	17.5	22.5	27.5
V1	10	1.86	1.57	1.34	1.04	1.29	1.46
V2	20	1.66	1.32	1.35	1.12	1.83	1.64
V3	30	1.43	1.48	1.24	1.43	1.63	1.74
V4	40	1.76	1.56	2.11	2.7	2.76	3.02
V5	50	2.16	1.82	2.89	2.58	2.84	4.52
V6	60	1.94	1.94	2.72	4.34	4.82	5.84
V7	70	1.62	2.32	2.73	4.55		

Thus obtained results are shown in Figure 7. The change in value of Ra parameter has been monitored for different traverse speeds and depths of cut.

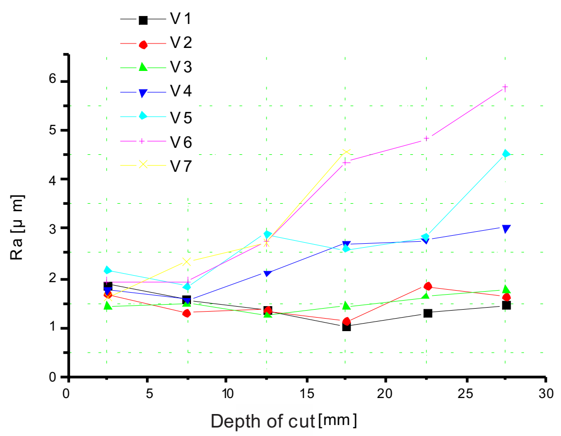


Figure 7. Effect of traverse speed on quality of machined surface of stainless steel Č 4580

Figure 7. indicates that at low traverse speed V1 no significant change in the value of Ra parameter occurs with the change of depth of cut, i.e. Ra parameter is almost constant for every depth of cut and it vaires between 1,04µm and 1,86µm, which can be subsumed under N7 roughness class. During machining process, with higher traverse speed, the change in values of Ra parameter is more distinct and it varies depending on depth of the cut. Furthermore, with low traverse speeds, no significant changes in the value of Ra parameter occur for different traverse speed.

5. CONCLUSION

The paper presents the results of the research concerning the traverse speed effect on the change in surface quality, i.e. the change in Ra parameter. It has been observed that the increase of traverse speed causes the increase in the machined surface roughness. The difference is sharper if the depth of cut is larger, or if the thicker materials are being machined. The value of Ra parameter is almost constant on the entire machined surface, when the traverse speed is low. Therefore, high quality of the machined surface can be achieved through the machining with abrasive water-jet by selecting the appropriate traverse speed.

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