INFLUENCE OF ABRASIVE MATERIAL QUANTITY ON SURFACE QUALITY GENERATED BY ABRASIVE WATER JET OPERATION

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Abstract: Water jet cutting is an unconventional technology used for materials processing. It is known to be one of the most versatile and rapid cutting methods that can be applied to process a greater variety of materials such: metallic materials, non-metallic materials, stone, glass etc. By comparing with the classical technologies, the water jet cutting presents the following advantages: it is rapid; it is silent and has a good cutting accuracy. The present paper is an experimental study regarding the influence of abrasive quantity on surface quality generated when low pressures of water jet abrasive cutting are used. Abrasive material is garnet grain size of # 80 and a hardness of 7.5 on the Mohs scale.

Key words: abrasive water jet, surface roughness, abrasive quantity.

1. INTRODUCTION

Water jet processing technology is one of the most recent unconventional methods used for materials processing in industry. Application of abrasive water jet cutting made possible good quality of products, flexibility of production and enlargement of economy. Abrasive water jet cutting is used in many industries, including the automobile, aerospace, and glass industries, to create accurate parts from hard-to-cut materials. Improvements in abrasive water jet machining technology results in significant gain in productivity in industry and also make the process suitable for adaptation for new applications than is currently being used, (Radovanovic, M., 2005, Janković, P., Radovanović, M., 2008). Processing water jet is divided into two processing procedures: pure water jet (for soft materials, food industry, textile industry, chemical and thin film materials, aluminium foil, plastic, leather, etc.) and water jet with abrasive mixture (for metallic materials: steel, stainless steel, bronze, aluminium, titanium alloys, stone, greate thickness granite etc.).
Meanwhile, the cutting performance, in terms of speed and accuracy, is also becoming more required. Abrasive water jet cutting technology offers the following advantages compared to many traditional and other non-traditional machining technologies: no thermal distortion; high flexibility; high machining versatility and small machining force, (Chen, L., Siores, E., Wong, W.C.K., 1996). On the other hand, disadvantages of water jet processing are: package material can't be processed, low cutting quality for thick materials, high processing cost (consumables are expensive).
The use of the abrasive water jet for machining or finishing purposes is based on the principle of material erosion under the jet hits. Each of the two jet components (the water and the abrasive material) has both a separate purpose and a common purpose. The primary purpose of the abrasive material within the jet stream is to provide the erosive forces, (Janković, P., Radovanović, M., 2008).
The main processes using water jet are water jet as fallows turning, milling, cutting, drilling, surface treatment (sandblasting), surface cleaning, etc.
The present paper investigates the influence of the abrasive material amount on the quality of the processed surface, namely on its roughness and dimensional precision.

2. EXPERIMENTAL CONDITIONS

In order to determine the abrasive material influence a material commonly used in industry OL 37 carbon steel (S 235) with thickness of 6.5 mm was used. The chemical composition of the used material is presented in Table 1.

Table 1. Chemical composition of the used material

OL 37 (S 235)	C	Si	Mn	P	S	N
	%	%	%	%	%	%
	0.130	0.250	0.580	0.013	0.008	0.010
	Cu	Cr	Ni	Mo	Al	V
	%	%	%	%	%	%
	0.320	0.080	0.100	0.013	0.033	0.001

The abrasive material used in the experiments was a garnet with a granulometry # 80, with Mohs scale hardness equal to 8 (figure 1), [4]. The used grains shape is angular. The machine used for material processing was Hydro-Jet Eco 0615, with a working pressure equL to 150 MPa. The used equipment is presented in figure 2. The main components of the water jet machine are: the water preparation tank, the multiplier, the abrasive cutting head and the disperser of abrasive.

Fig. 1 Garnet grains [4]

The determination of the surface roughness was performed using a HOMMEL Tester T 500. The coordinate measuring system Tesa micro - hite 3D with computer interface was used in order to determine the machined parts dimensions.

Fig. 2 Water jet cutting machine Hydro-jet Eco 0615

2.1 Analyse of the processed surface quality

To determine the influence of the abrasive amount on surface quality the following factors were taken into account: dimensional accuracy (width of the processed surface at the jet inlet - Li, width of the processed surface at the jet outlet - Lo, deviation from the perpendicularity - u and inclination angle of the processed surface - α) and roughness of processed surface - Ra. The factors describing the quality of water jet processed surface are presented in figure 3 according to ISO / WD / TC 44 N 1770 of 2010 [5].

Measuring of the deviation from perpendicularity was done as shown in Figure 4. It represents the difference between the entrance width and the exit width.

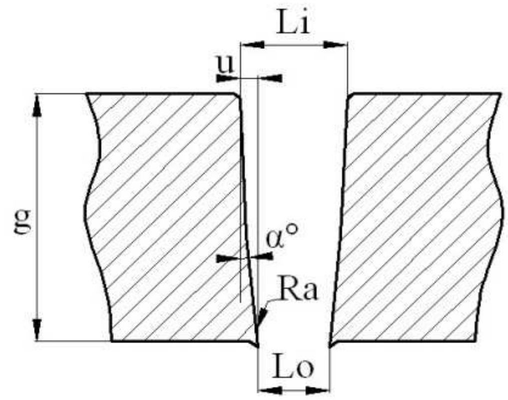

Fig. 3 The components of the surfaced processed with water jet with abrasive mixture, [4]

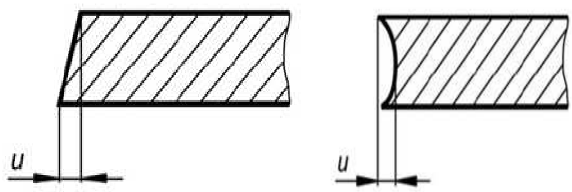

Fig. 4 Deviation from perpendicularity, [5]

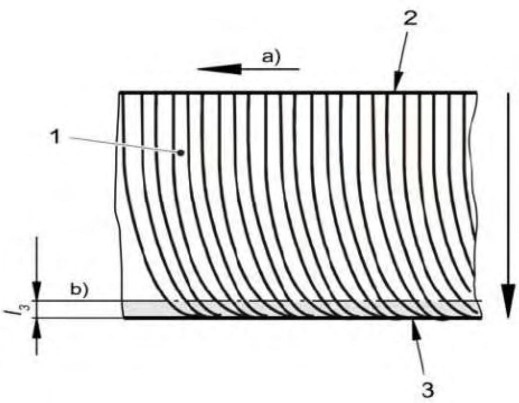

Fig. 5 Of the processed surface, [5]:
1-processed surface; 2 – jet inlet; 3 – jet outlet; l_3 – roughness measuring distance; a – jet movement direction; b – roughness measuring line.

2.2 Determination of the dimensional accuracy of the water jet processed parts

The study regarding the dimensional accuracy of the water jet machined parts was performed on the following three different surfaces: the plane surface with a length equal to 50mm, the circular surface - the outer radius equal to 15mm, the inner surface with a diameter φ = 10 mm. Figure 6 are represents the shape and size of workpiece.

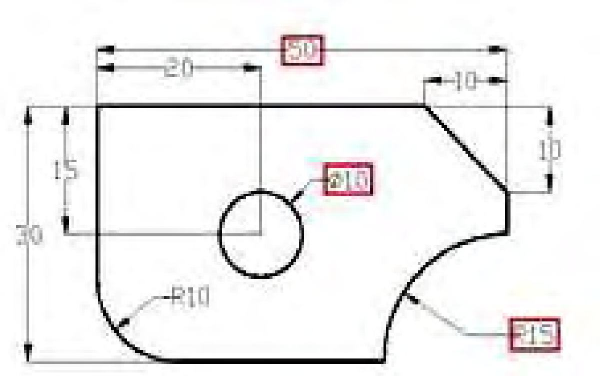

Fig. 6. Shape of the water jet processed piece

Dimensional accuracy measurement of the workpiece processed with water jet with abrasive mixture was made at jet inlet and as well as at the jet outlet. The planes on which the deviations were measured are as follows: 1st plane was set at -1 mm from the jet inlet and the 2nd plane was set at -5 mm from the jet inlet.

3. RESULTS AND DISCUSSIONS

The processed surface quality using different amounts of abrasive material was studied based on the following parameters: dimensional accuracy (width of the processed surface at jet inlet (Li), width of the processed surface at jet outlet (Lo), deviation from perpendicularity (u), processed surface inclination angle (α) and roughness (Ra). The quantities of abrasive material used in experimental trials were as follows: 300, 500 and 700 g / min. The material thickness was equal to 6.5 mm. Table 2 presents the working parameters used in experiment.

Tabel 2 Constant parameters used at the determination of the influence abrasive mixture quantity

Parameter	Unit	Value
Working pressure (P)	[MPa]	150
Distance between the working head and the part (h)	[mm]	3
Feed rate (V_f)	[mm/min]	50

a. Dimensional accuracy of the surface processed with water jet

The resulted values for the width of the processed surface at the jet inlet as a function of the quantity of abrasive material used are shown in Table 3. The graphical representation of variation of the surface width jet inlet processed by different amounts of abrasive material is presented in Figure 7.

From the analysis of obtained data it can be observed that the increase of the amount of abrasive material used leads to the increase of the width value of the processed surface at jet inlet. This variation can be explained by the fact that to the increase the amount of abrasive material the degree of erosion of the processed surface also increases, and that implies an increase in the width of the processed surface at jet inlet.

Tabel 3. Width of the processed surface at the jet inlet as a function of the quantity of abrasive material

Parameter	Unit	Value		
Abrasive mixture quantity (Q)	[g/min]	300	500	700
Width of the processed surface at the jet inlet (L_i)	[mm]	1.05	1.11	1.23

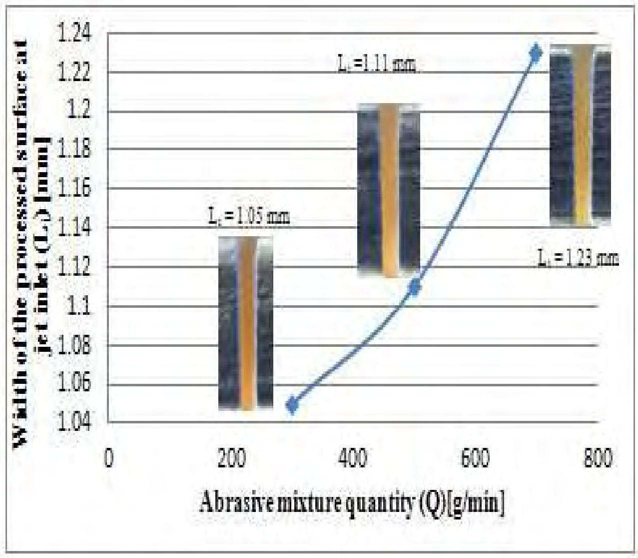

Fig.7. Variation of the width of the processed surface at the jet inlet with the abrasive mixture quantity

The width values for the processed surface at jet outlet obtained from the processing with different amounts of abrasive material are presented in Table 4.

Table 4. Width of processed surface at jet outlet obtained by the processing with different amounts of abrasive material

Parameter	Unit	Value		
Abrasive mixture quantity (Q)	[g/min]	300	500	700
Width of the processed surface at the jet outlet (L_0)	[mm]	0.97	1.03	1.12

The graphical representation of the surface width variation at the jet outlet depending on the amount of abrasive material is presented in Figure 8.

From the analysis of the obtained data it can be seen that with increasing of the amount of abrasive material the width of the processed surface jet outlet increases.

In the case of the use of a larger amount of abrasive the width of the processed surface at the jet outlet increases as in the same time a larger amount of abrasive material enters in contact with the processes surface and surface erosion is more pronounced.

Table 5 presents the values obtained for the deviation from perpendicularity in the case of abrasive water jet process using various amounts of abrasive material.

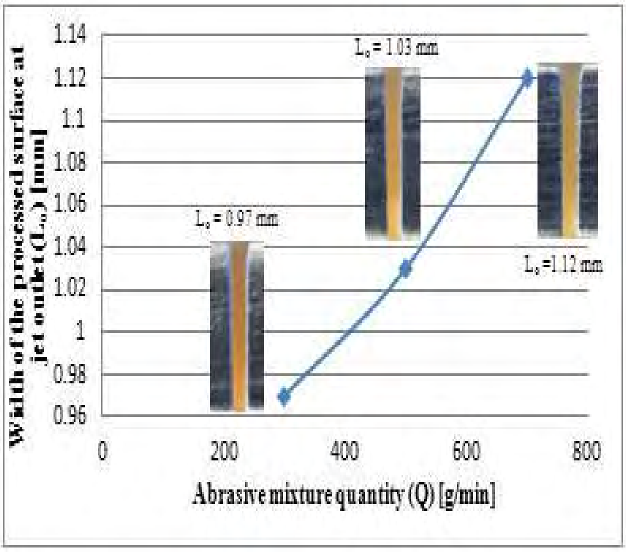

Fig. 8. Variation of the width of the processed surface at the jet outlet with the abrasive mixture quantity

Tabel 5. Deviations from perpendicularity in the case of abrasive water jet process using various amounts of abrasive material

Parameter	Unit	Value		
Abrasive mixture amount (Q)	[g/min]	300	500	700
Deviation from perpendicularity (u)	[mm]	0.12	0.05	0.03

The graphical representation of variation of the deviation from perpendicularity with the amount of abrasive material is presented in figure 9.

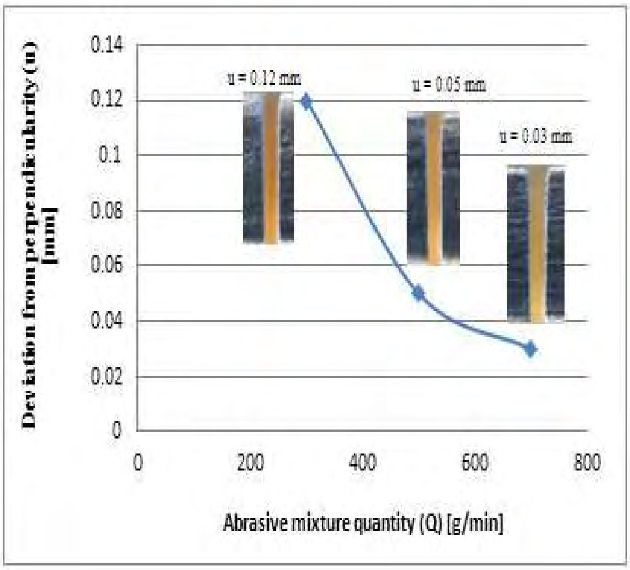

Fig. 9. Variation of the deviation from perpendicularity with the amount of abrasive material

From the analysis of the obtained data it can be seen that the deviation from perpendicularity decreases to the increase of the amount of abrasive material. This variation can be explained by the fact that the increase of the abrasive amount leads to a more uniform erosion of the processed surface.

In Table 6 are presented the values of the inclination angle as a function of quantities of the abrasive material.

Table 6. Variations of the inclination angle with the quantities of the abrasive material

Parameter	Unit	Value		
Abrasive mixture amount (Q)	[g/min]	300	500	700
Inclination angle (α)	[°]	1.12	0.7	0.6

Figure 10 presents the variation of the inclination angle with the amount of abrasive material.

From the analysis of the obtained data it can be concluded that the use of a smaller amount of abrasive material lead to a greater inclination angle. This variation is due to the fact that the surface erosion degree becomes more constant due to the larger quantities of abrasive material.

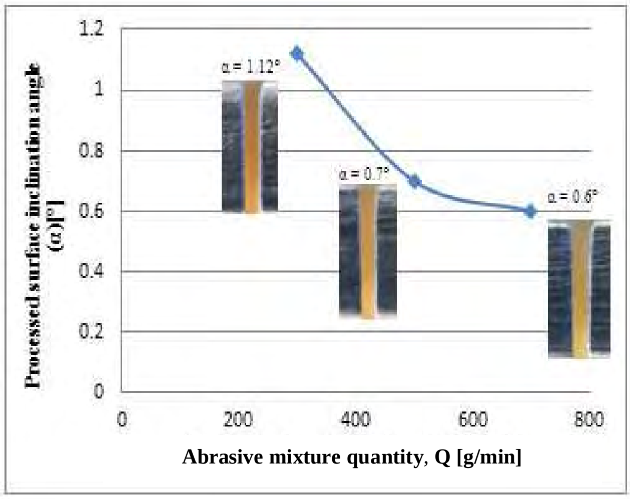

Fig. 10. Variation of the inclination angle with the amount of abrasive material

b. Roughness of the water jet processed surface

Table 7 presents the roughness (Ra) values obtained in the case of surfaces processed with abrasive water jet using various quantites of abrasive material.

Table 7. Surface roughness Ra obtained by material processing with different abrasive mixture quantities

Parameter	Unit	Value		
Abrasive mixture quantity (Q)	[g/min]	300	500	700
Roughness (Ra)	[µm]	4.03	3.87	3.96

The graphical representation of variation of the surface roughness as a function of the amount of abrasive material is presented in figure 11.

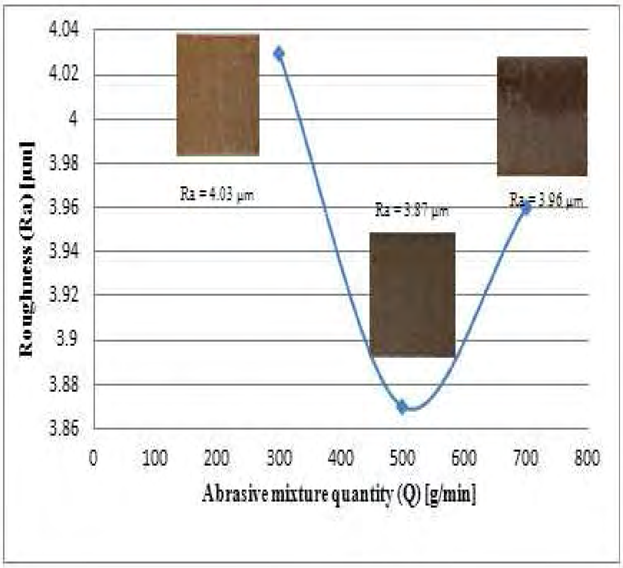

Fig. 10. Surface roughness variation with the amount of abrasive material

From the analysis of the obtained data it can be seen that the surface roughness varies with the variation of the amount of abrasive material. This variation is due to the fact that a smaller amount of abrasive is driven by the water jet. The optimal abrasive amount determined for the HYDRO JET ECO 0615 was equal to 500 g/min; over this value the roughness starts to increases, because of the apparition of more pronounced surface erosion. However, by considering other factors that influence the surface quality the roughness is not substantially influenced by the amount of abrasive used.

Also, at a large amount of abrasive, the water jet transmits less kinetic energy to the abrasive grains and in the focussing will occur the phenomenon of collision of the abrasive particles, phenomenon that leads to the decrease of the kinetic energy and processing performance.

c. Dimensional accuracy of parts processed with abrasive water jet

The experimental study was also conducted in order determinate how much the quantity of abrasive material influence the dimensional accuracy of the parts processed with abrasive water jet. The measured surfaces were presented in paragraph 2.2. The part shape was chosen because it presents different forms: linear processing, outer circular processing and inner circular processing.

Table 8 summarizes the values of deviations from length of the plane surface obtained by abrasive water jet processing.

Tabel 8. Variation of the processed surface length deviation with the abrasive amount

Abrasive mixture amount Q [g/min]		300	500	700
Flat surface length deviation	Inlet -1 mm	-0.158	-0.898	-0.398
	Outlet -5 mm	-0.133	-0.859	-0.341

The graphical representation of the variation of processed surface length deviation is presented in figure 11.

From the analysis of the obtained data it can be seen that the surface length deviation had the minimal value when the amount of abrasive used was equal to 300 g/min. The increase of the abrasive amount to 500 g/min leads to the increase of the length deviation to – 0.859 mm.

Further increase in the abrasive amount will lead to linear decrease of the length deviation.

Table 9 presents the values of deviations from the radius of the outer circular surface obtained by abrasive water jet processing using various amounts of abrasive material.

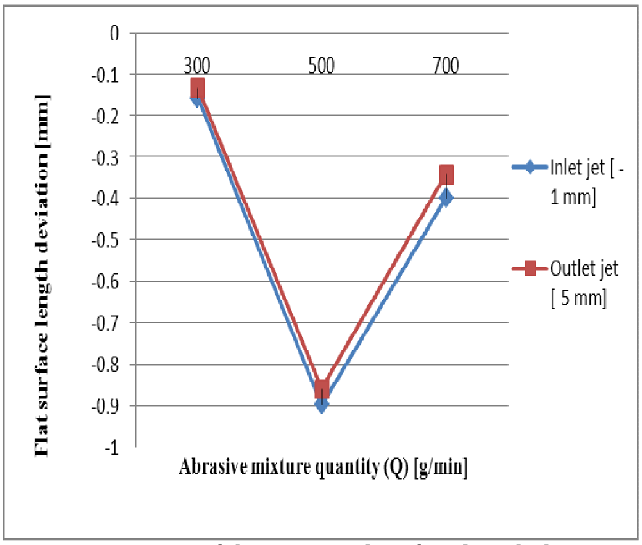

Fig. 11. Variation of the processed surface length deviation with the abrasive amount

Tabel 9. Deviations from the radius of the outer circular surface obtained by abrasive water jet processing using various amounts of abrasive material

Abrasive mixture amount Q [g/min]		300	500	700
Deviations from the radius of the outer circular surface	Inlet -1 mm	0.059	0.117	0.142
	Outlet -5 mm	0.011	0.057	0.087

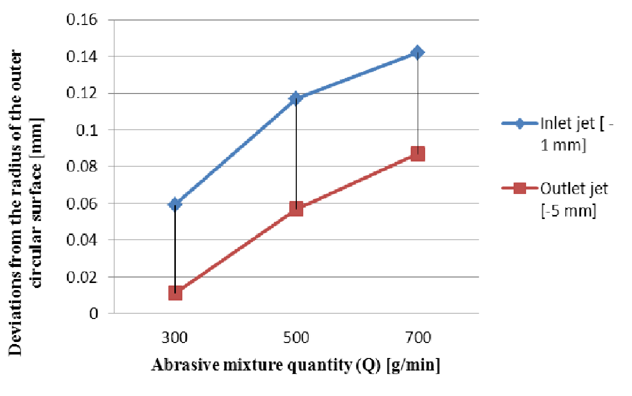

Fig. 12. Deviations from the radius of the outer circular surface variation with the abrasive material amount

The data obtained from the abrasive water jet processing with different amounts of abrasive material lead to conclusion that the smallest deviation was obtained when the processing was realised with 300 g/min of abrasive material. For the radius of the outer circular surface processing the deviation increased to the increase of the abrasive material amount (figure 12).

Tabel 10. Variation of the deviations from the diameter of the inner circular surface with the abrasive amount

Abrasive mixture amount Q [g/min]		300	500	700
Deviations from the diameter of the inner circular surface	Inlet -1 mm	0.012	0.024	0.113
	Outlet -5 mm	0.016	0.045	0.138

From the obtained data it could be seen that the increase of the abrasive material amount lead to the increase of the deviations from the diameter of the inner circular surface (figure 13). It could also be observed that on the material thickness this deviation was different when the abrasive material amount increased.

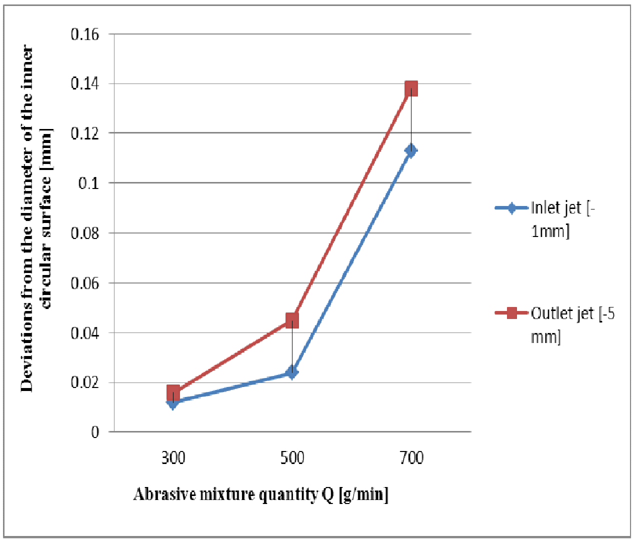

Fig. 13. Variation of the deviations from the diameter of the inner circular surface with the abrasive amount

4. CONCLUSIONS

The increase of the abrasive quantity leads to the increase of the processed surface width at both jet inlet and outlet, determining the decrease of the processed surface deviation from perpendicularity and jet inclination angle. The processed surface roughness decreases to the increase of the abrasive quantity till 500 g/min; the further increase of the abrasive quantity lead to roughness increase and or even the appearance of striations. In the case of the plane surfaces, especially of the length equal to 50 mm, the deviation from plan surface length was obtained for an amount of abrasive material equal to 300 g/min. The value deviation was equal to – 0.158 mm for a thickness equal to 6.5 mm. In the case of the outer circular surface processing, the deviation from the radius dimension was different on the both plans; the smallest deviation was obtained for a quantity of abrasive material equal to 300 g/min. The increse of the abrasive material amount leads to the increase of the deviation from radius and to increase of the inclination between the inlet and outlet planes.
For the inner surface diameter processing with 300 g/min abrasive material the value of the obtained deviation is equal to 0.016mm. If we consider the ISO 2768 standards, the parts processed with water jet are within the imposed standards.

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