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INFLUENCE OF ABRASIVE FLOW RATE ON SURFACE QUALITY IN ABRASIVE WATER JET CUTTING

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ABSTRACT
Because of its significant advantages of low thermal influence on workpiece and possibility of cutting different type of materials, the abrasive water jet cutting is more and more present in industry. One of the bigger costs during abrasive water jet cutting is the cost of abrasives. Recommended and required abrasive flow rate is mostly determined by type of workpiece material and its thickness and pump pressure. In intent to reduce the abrasive mass consumption in cutting, some experiments were done and the paper presents the results of changing the abrasive flow rate (mass flow) and its influence on surface cut quality in abrasive water jet cutting. Abrasive saving possibility and also the influence of cutting nozzle distance from workpiece surface on surface cut quality in abrasive water jet cutting are discussed in this paper.
Keywords: AWJ, abrasive flow rate, roughness

1. INTRODUCTION
Abrasive Water Jet Machining is a relatively new nonconventional material removal technology, which are increasingly used in industry. Exceptional opportunities provided by this process are savings in time and materials, with great productivity and universality of the process which is manifested in capability of cutting virtually any material, make all sorts of shapes with only one tool. In cutting there is no heat affected zone on workpiece, there are small feed forces during cutting, so there is no need for clamping[1,2,3]. In addition, this process is environmentally-friendly, and easy to maintenance. According to the various manufacturers [4,5] this technology has the fastest growth of sales of machines in relation to all other conventional and unconventional cutting processes.
Unlike WJ, in the abrasive water jet AWJ is used and abrasive materials, which allows the cutting of nearly all materials, and jet power in relation to the ordinary water-jet is from 100 to 1000 times higher. In that process the high pressure is used to jet acceleration at the exit from the nozzles, where the taper is converted it into jet kinetic energy, and then in contact with the material in the mechanical energy of erosion. At pressure of approximately 2500 bar speed jet is Mach 2, with a pressure of 4000 bar speed jet is approximately Mach 3. Because the AWJ cutting process is realized by erosion of material particles, in the cutting the thicker material stream deflects backwards, and that is cutting error. This decrease in the cut surface quality can be avoid by reducing the speed of cutting or increasing the combination of cutting head.

Most AWJ systems work with a combination of cutting head 1 ÷ 3, or the diameter of abrasive nozzle is three times greater than the diameter of the water nozzle. With this combination of cutting head the working life of components is the longest and the best cutting characteristics are achieved.
In the abrasive water jet cutting, abrasive materials represent the largest cutting cost, and due to the reduction of production costs, the aspiration is to decrease the needed abrasive mass flow [6, 7]. However, the savings in abrasive materials can have very negative reflection on the cutting speed and thus on the productivity of the entire process.
Small mass flow of abrasive materials reduces the cutting speed, thus increasing cutting time. Excessive mass flow overload water jet that can not be sufficient to accelerate the abrasive particles and that again reduces cutting speed. So, in every of abrasive water jet process it is very important to determine the optimal mass flow of abrasive materials in which the maximum cutting speed is achieved and cost of abrasive materials is minimal.
Abrasive saving possibility and also the influence of nozzle distance from workpiece surface on surface cut quality in abrasive water jet cutting are discussed in this paper.

2. EXPERIMENTAL CONDITIONS

Abrasive saving possibility is investigated on abrasive water jet cutting of workpiece material C65, thickness of steel plate was 6 mm. CNC Abrasive waterjet machine WJ-1510B-2ZS-D, was produced by PTV Company, Czech Republic, [8]. The machine has two cutting heads for the high normal or abrasive water jet, for cutting max. dimensions 200x100 cm and maximum pressure of 4100 bar.
In these experiments as the abrasive material is used Granat, the most popular abrasive in abrasive waterjet cutting with universal granularity 80. Granat is available and also highly represented in the foreign market because it is capable of cutting an extremely wide range of materials, yet is soft enough to give long life of mixing tube but, it is very expensive and in imports in Croatia it must be taken in large quantities.
For measuring roughness parameters of cutting surface was used measuring device Mitutoyo SP-201. Measurement is carried out in the middle of the sample thickness and roughness is shown with a measured parameter, arithmetic surface roughness, Ra. Measurements were performed in the Laboratory for machine tools, Faculty of Mechanical Engineering and Naval Architecture in Zagreb.

3. EXPERIMENT 1

Experiment 1 wanted to examine the impact of reduction quantities of abrasive flow rate on the quality of cutting surface. Along with the change of abrasive flow rate, the other cutting parameters as cutting speed, pressure and a combination of cutting heads all the time were the same. So, cutting speed was 200 mm / min, diameter of water nozzle 0.33 mm, diameter of abrasive nozzle 1 mm and jet pressure 3600 bar. Setting larger blend diameters, mass abrasive flow rate is increasing so, in experiment the used blend diameters were 3-7mm, the abrasive mass flow of 145 g/min for the blend diameter 3mm to 365 g/min for the blend diameter 7mm.
Results of measuring surface roughness of cut samples, with a certain blend diameter and the corresponding mass flow of abrasives, are given in Table 1 and shown graphically in Figure 1.

Table 1. Surface roughness in dependence of abrasive flow rate

Sample No.	Blend diameter, mm	Abrasive flow rate, g/min	Surface roughness R_a, μm
1.	3	145	5,41
2.	4	185	5,01
3.	5	256	5,19
4.	6	306	5,68
5.	7	356	4,89

From the diagram in Figure 1 it can be seen that the quantities of abrasive flow rate not too much impact on the quality of cutting surface samples. Medium roughness values of samples were in the same orders of magnitude, and in dependence on abrasive mass flow differ very little.

AWJ machine manufacturer recommendation, for the combination of cutting heads used in this experiment, is that abrasive mass flow must not be reduced more than 306 g / min, and with that mass flow of abrasives is cutted sample no. 4. Sample no.1 was cutted with 145 g / min, which is even double smaller amount of abrasive flow rate than the recommended minimum. It is evident that the measured surface roughness of the sample no.1 is slightly larger than the sample no. 5 which was cutted with a maximum of 356 g / min.

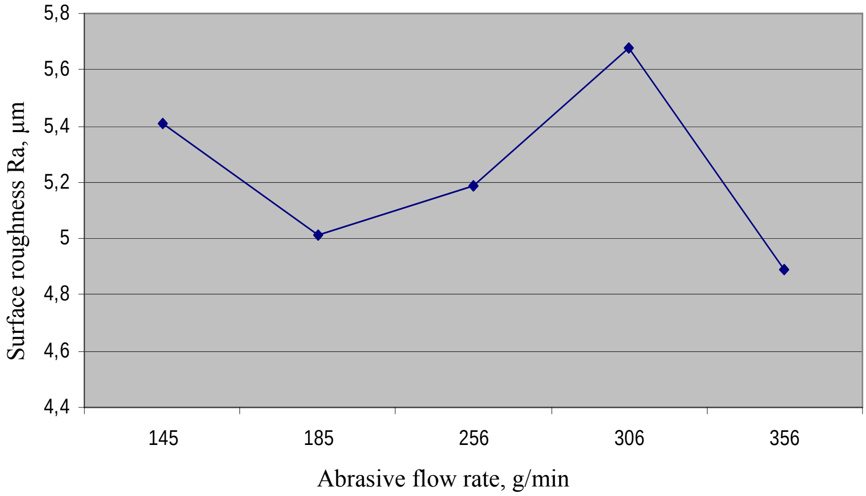

Figure 1. Influence of abrasive flow rate on workpiece surface roughness

Thus can be concluded that in some cases of waterjet cutting, the abrasive flow rate (mass flow) may be reduced in relation to the manufacturer's recommended value, because the quality or the surface roughness of cut samples remain in the same orders of magnitude.

4. EKSPERIMENT 2

Besides abrasive flow rate, the cutting nozzle distance from workpiece surface have also the influence on workpiece surface cut quality. In Table 2 are given the results of the influence of cutting nozzle distance from workpiece surface on measured surface roughness of cut samples, and in Figure 2 these values are shown graphically.

Table 2. The cutting nozzle distance from workpiece surface and obtained surface roughness

Sample No.	Cutting nozzle distance from workpiece surface, mm	Surface roughness R_a, µm
1.	3	5,41
2.	5	4,6
3.	7	4,78
4.	9	5,34
5.	11	5,08

Diagram from Figure 2 shows that the obtained results did not confirm the theoretical and literature knowledge that surface roughness increase with increasing cutting nozzle distance from workpiece surface. Surface roughness in the experiment reduces with increase in cutting nozzle distance from workpiece surface, when it changes from 3 mm to 5 mm and from 9 mm to 11 mm.
Possible reasons for the unexpected decrease of workpiece surface roughness with increasing cutting nozzle distance from workpiece surface are cutting speed of 200 mm/min, a big-jet power obtained by 3600 bar pressure, a combination of cutting head 0.33 mm/1mm and relatively small workpiece thickness. Addition was used and a large abrasive flow rate of 356 g/min, which is due to high jet

power accelerates enough the Granat so in a larger cutting nozzle distances cutting conditions are still good, which bearing on the quality of surface roughness of cut samples.

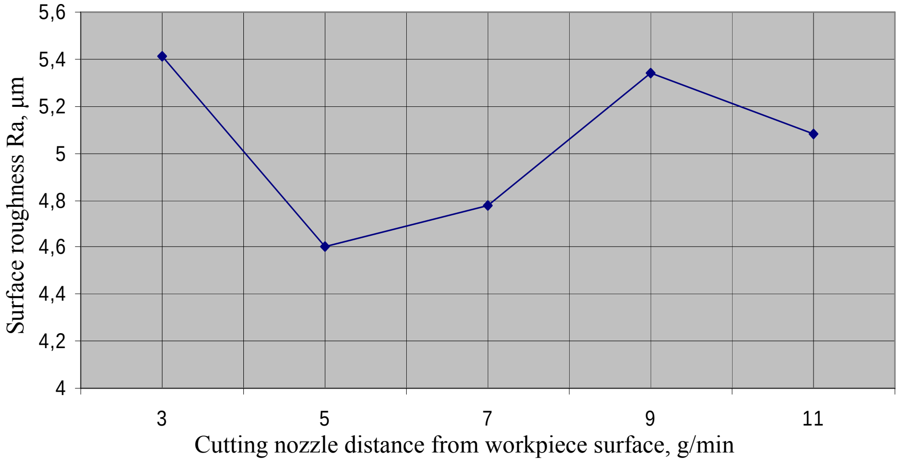

Figure 2. Influence of cutting nozzle distance from workpiece surface on workpiece surface roughness

5. CONCLUSION

Experiment 1, examined the impact of reduction quantity of abrasive flow rate on the quality of cutting surface since the largest part of the waterjet costs belongs to abrasive material Granat. From the results obtained by experiment it can be concluded that the abrasive flow rate (mass flow), particularly in the waterjet cutting of ticker and softer materials, may be reduced below the values recommended by the manufacturer. That is because in cutting with the same cutting speed the surface roughness of cut samples does not change much at lower abrasive flow rate.

This directly saves on expensive abrasive materials without reducing cutting speed and productivity. This conclusion can not be taken as a rule, but it certainly says that it is advisable on a single piece workpiece material prior to cutting exams the influence of smaller abrasive flow rate. If such an examination gives a satisfactory result of the surface roughness quality, reduce the abrasive flow rate of 100 g / min, in the one hour of cutting could save about 6 €.

Experiment 2 in which the observed increase of cutting nozzle distance from workpiece surface, measured surface roughness of cut samples has not acted as expected and was not increased. With greater cutting nozzle distance appeared only the spread sandblasting area at the workpiece cut. This phenomenon certainly needs to take into account when cutting the workpieces which require different cutting nozzle distances because of workpiece wave shaped surface.

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