15th International Research/Expert Conference
”Trends in the Development of Machinery and Associated Technology”
TMT 2011, Prague, Czech Republic, 12-18 September 2011

EXPERIMENTAL INVESTIGATION OF SURFACE ROUGHNESS OBTAINED BY ABRASIVE WATER JET MACHINING

Veselko Mutavgjic
I.G.Kovačića 24, Jadranovo
Municipality of Crikvenica
Kralja Tomislava 85, Crikvenica
Croatia

Zoran Jurkovic
Faculty of Engineering
University of Rijeka
Vukovarska 58, Rijeka
Croatia

Marina Franulovic
Faculty of Engineering
University of Rijeka
Vukovarska 58, Rijeka
Croatia

Milenko Sekulic
Faculty of Technical Sciences
University of Novi Sad
Trg Dositeja Obradovica 6, Novi Sad
Serbia

ABSTRACT
Abrasive water jet machining is classified a non-conventional machining procedure. Abrasive water jet machining uses water jet under high pressure as a tool, with added particles of abrasives. The most significant characteristic of the abrasive water jet cutting technology is cold cutting, which does not have a thermic effect on the material. The objective of the experimental investigation is to conduct research of the machining parametres' impact on surface roughness of the machined parts, and derive conclusions referring to the manner in which certain machining parametres affect surface roughness. Experimental investigation was conducted in the way that samples of two different materials were cut on the machine using different machining parametres. Measurement of different surface roughness parametres has been conducted after the cutting.
Keywords: abrasive water jet machining, surface roughness, experimental investigation

1. INTRODUCTION

Water jet machining is suitable for cutting plastics, foods, rubber insulation, automotive carpeting and headliners, and most textiles. Harder materials such as glass, ceramics, concrete and tough composites can be cut by adding abrasives to the water jet during abrasive water jet machining, which was first developed in 1974 to clean metals prior to their surface treatment. The addition of abrasives to the water jet enhanced the material-removal rate and produced cutting speeds between 51 and 460 mm/min. Generally AWJM cuts 10 times faster than the conventional machining methods used for composite materials [1]. Advantages of abrasive water jet machining technology:

- There is no thermic effect on the material, and there are no changes in its structure
- Minimum influence of jet power on the material being cut, there are no micro-cracks
- In the regular working process, cutting of materials, minimum quantity of dust is created
- Cutting without smoke and gas emission, which can occur in the process of piercing
- There are no chemical effects on the material
- High-quality cut without burr, cutting edge and the surface do not require additional machining
- Precision of the cut is relatively high and very similar to classic machining
- Material thickness ranges from foils to very thick half-manufactured products
- Possibility of cutting complex and complicated forms
- It is also possible to cut materials which are otherwise hard to separate

- It is possible to cut layered materials with very complex characteristics of individual layers and composites

Disadvantages of abrasive water jet machining technology:

- In the linear high speed cutting, the cut obtains V profile
- In the process of high-speed cutting of inner angles, water jet may cause indents in the material
- In the process of high-speed cutting of circles and arches, a deviation of the water jet may occur
- Materials affected by corosion must be protected from corosion after cutting
- Machining of very hard materials is difficult or impossible

2. EXPERIMENTAL PROCEDURE

The objective of the experiment is to derive conclusions based on the measured surface roughness, in which manner certain machining parametres affect surface roughness of the workpiece, examined for various materials of different thickness. In order to derive optimal machining parametres for certain materials, it was necessary to conduct the experiment, and obtain the most favourable machining parametres in real conditions, which will result in minimum surface roughness.

2.1. Experimental conditions

Experimental investigation was conducted on the NC3015 machine, Water Jet Sweden. The machine is triaxial, its dimensions are 3 m × 1,5 m. High pressure pump Streamline SL-IV 50 is a product of Ingersoll Rand, 37 kW, of maximum pressure of 410 MPa. Measuring of surface roughness was conducted on the machine type T1000 basic, by manufacturer Hommel-tech. Measuring of surface roughness of the workpiece shall be conducted for two surface roughness parameters; *Rz* maximum height of roughness profile, *Ra* arithmetical mean deviation of roughness profile. Sample materials are the following: stainless steel (EN 10088-3), Aluminium (EN AW-5083). The abrasive used in the experiment is Garnet 80. Mesh grain size equals from 300 to 150 μm. In the experimenting process, specific conditions were set on the machine and shall not be changed during the experiment. The water nozzle (orifice) is sapphire, and the diametre of the nozzle equals 0,254 mm. The abrasive water nozzle is made of carbide, 0,76 mm in diameter. The cutting angle of 90°, i.e. abrasive water nozzle is vertical in relation to the machining surface [2].

Figure 1. Cutting of the sample, machine NC3015 and measuring of surface roughness on the machine T1000 basic

2.2. Experimental plan

Samples of dimensions 100 x 20 mm were cut out of the boards of greater dimensions, which were used for measuring of surface roughness. After the machining of samples, surface roughness of each sample was measured. Measuring was conducted in three places per each sample, at the beginning, in the middle and at the end of the cut. Finally, average value of surface roughness parameters was calculated from the obtained results. Figures for various parameters in relation to the measured surface roughness values were designed based on data obtained in this way. Changeable machining parameters which will be set on the machine in order to derive conclusions referring to how they affect quality of the machined surface are the following. Material type is a parameter of the experiment which shows the quality of the machined surface for various materials. The following changeable parameter is abrasive flow rate, i.e. its impact on the surface quality for two materials. An important changeable parameter is also stand-of distance. Water pressure will change on two levels, and water flow rate will also be changed for each change of the pressure. Traverse rate, i.e. cutting speed is a parameter which varies on three levels. It may be considered a crucial parameter for machining productivity. The desired machining quality and optimally set parameters will provide the greatest cutting speed for certain surface quality, which will achieve maximum possible productivity. The experiment is conducted by specific methodology, i.e. by using the Taguchi's Experiment Plan (Table 1 and 2).

Table 1. Taguchi's plan of the 2nd level, with parameters and their values

Parametres	**1**	**2**
A – material	stainless steel	Aluminum
B – abrasive flow rate (g/min)	220	350
C – stand-of distance (mm)	2	4
D – water pressure (MPa)	220	330
E – traverse rate (mm/min)	100	300
F – sample thickness (mm)	2	4

Table 2. Taguchi's plan of the 2nd

Exp №	**Parametres**						
	A	**B**	**C**	**D**	**E**	**F**	**G**
1	1	1	1	1	1	1	1
2	1	1	1	2	2	2	2
3	1	2	2	1	1	2	2
4	1	2	2	2	2	1	1
5	2	1	2	1	2	1	2
6	2	1	2	2	1	2	1
7	2	2	1	1	2	2	1
8	2	2	1	2	1	1	2

3. ANALYSIS OF RESULTS

Analysis of figures obtained on the basis of results of experimental investigation, conclusions are derived on the way a certain machining parametre affects surface roughness. Figure 2 shows the impact of abrasive flow rate on the Rz parameter for different materials. Abrasive water jet machining was conducted by three different water flow rates, i.e. 220 g/min, 285 g/min, and 350 g/min. The results of surface roughness measuring were entered in the figure. The other parameters are the same for all measurements; thus, stand-of distance equals 2 mm. Water pressure equals 220 MPa, traverse rate 200 mm/min, and sample thickness 2 mm for all materials. Taking into consideration that water pressure equals 220 MPa, abrasive water flow equals 1,41 l/min. The parameter of roughness of the machined stainless steel surface continuously declines when abrasive flow rate increases. Aluminium shows more unfavourable results of the roughness parameter *Rz* of the machined surface. Surface roughness of aluminium is up to 25% higher, compared to stainless steel. It is important to note that roughness parameter *Rz* declines much faster (the steepest) when abrasive flow rate for aluminium is increased. Figure 3 shows the impact of water pressure parametre on the two examined materials. The other parametre remained unchained; thus, abrasive flow rate equals 220 g/min, stand-of distance 2 mm, traverse speed 200 mm/min, sample thickness 2 mm. Water pressure level was 220 MPa and 330 MPa for both materials. The figure shows that water pressure affects the *Rz* parametre, as well as abrasive flow rate. Stainless steel shows the best surface machining quality; when water pressure increases, surface roughness quality also increases, taking into consideration the *Rz* parametre.

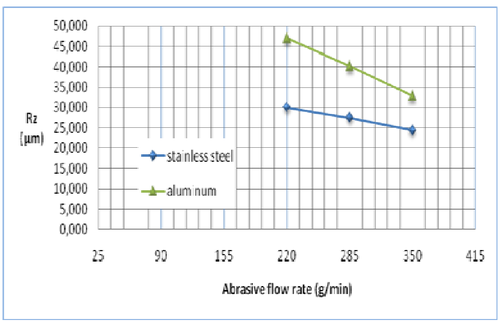

Figure 2. Graph of Rz dependence on material type and abrasive flow rate

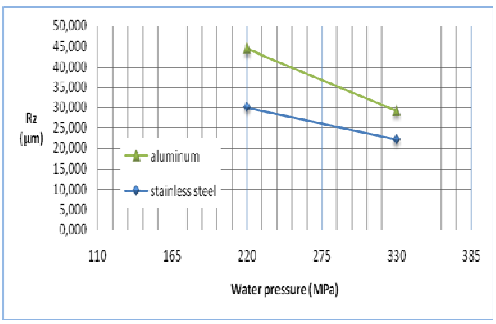

Figure 3. Graph of Rz dependence on material type and water pressure

Aluminium shows an increase in surface roughness quality when water pressure increases, and a somewhat lesser quality of surface roughness than stainless steel, but when water pressure increases, it shows the greatest increase in the machined surface quality.

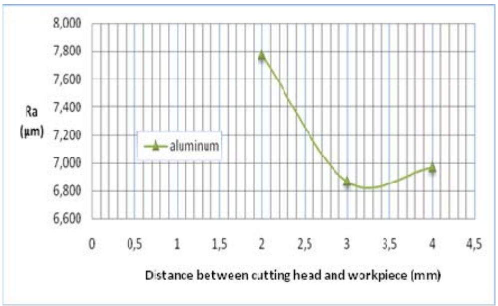

Figure 4. Graph of Ra dependence on the distance between cutting head and workpiece

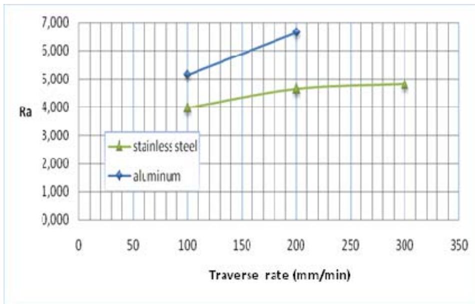

Figure 5. Graph of Ra dependence on the type of material and traverse rate

Figure 4 shows that stand-of distance affects the *Ra* parametre. All machining parameters are constant, and the experiment was conducted on an aluminium workpiece. Abrasive flow rate equals 220 g/min, water pressure 220 MPa, traverse speed 200 mm/min, material thickness 2 mm, and stand-of distance 2 mm, 3mm, 4 mm. Great nozzle speed does not provide the best surface roughness results. The figure shows that the greatest surface roughness is realised on the stand-of distance of 2 mm, and it grows as the distance between the workpiece and the nozzle increases to the distance of 3,2 mm. The least surface roughness *Ra* is realised at this distance for the set machining parametres. When the stand-of distance increases further, quality of the machined surface declines. Figure 5 shows the impact of traverse cutting speed on the Ra parameter for the two materials. The other machining parameters are constant for each material. Stainless steel has abrasive flow rate of 220 g/min, stand-of distance of 2 mm, water pressure 220 MPa, sample thickness of 2 mm. For Aluminium, abrasive flow rate equals 220 g/min, stand-of distance 4 mm, water pressure 220 MPa, sample thickness 4 mm. Aluminium shows a greater decline in the quality of the machined surface than stainless steel when traverse speed is increased [2].

4. CONCLUSIONS

Abrasive water jet machining is machining which has much more advantages than disadvantages. The objective of the paper was to analyse the impact of several machining parametres on surface roughness. Maximum height of the roughness profile *Rz* was controlled in the process, as well as mean arithmetic deviation of the roughness profile *Ra*. Analysis of the obtained figures has indicated the following changes. Increase in the abrasive flow rate, and, likewise, increase in water pressure, provide improved results of surface roughness. The impact of the distance of the abrasive nozzle on the example of aluminium workpiece produced optimal value which, according to experimental investigation, amounts 3,2 mm. Surface roughness of machining increases when traverse speed increases. The following step in further experimental research is optimisation of machining parametres with the objective to minimise the roughness of the machined surface.

5. ACKNOWLEDGMENT

The authors wish to thank the management of the company Scam Marine for the AWJ machine and materials supplied for the experiments and also for technician support during execution of the tests.

6. REFERENCES

[1] El – Hofy H.: Fundamentals of Machining Processes: Conventional and Nonconventional Processes, Taylor & Francis Group, Boca Raton, 2007.

[2] Mutavgjić V.: Istraživanje površinske hrapavosti dijelova dobivenih abrazivnim vodenim mlazom, University of Rijeka, Faculty of Engineering, Rijeka, 2010.