



EXPERIMENTAL RESEARCH OF INFLUENCE OF QUANTITY OF ABRASIVE MATERIAL AND WATER FLOW ON CUTTING GAP AT HYDRO-EROSION AND THEIR INFLUENCE ON ENVIRONMENT

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Abstract:

The global environmental trends lead to utilizing of so called „clean technologies“ with minimum environmental impact. In case of high-speed continual waterjets application it is possible to expect substantial raise of products manufacturing efficiency.

Experimental research deals with the influence of quantity of abrasive material and flow of high-pressure water on the width of water jet and simultaneously on quality of cutting gap at cutting with hydro-abrasive erosion. The research solves with possibilities of various combination of flow rate of high-pressure water, it means, various rates of water and abrasive material, diameters of nozzles with relation to various cutting speeds and various granularity in mesh of abrasive material for high pressure water jet. Based on the chosen cutting parameters and based on the evaluation of cutting surface quality, there were defined the set of parameters, which have the biggest influence on the cutting gap width, the width of water jet and the quality of cutting area.

The obtained results were summed into concrete advices for practice.

Keywords:

Water jet, water nozzle, cutting gap, material, quality

INTRODUCTION

The analysis of the using and recycling abrasive material from a fluid in abrasive water jet cutting process was the aim of the research. The research has been conducted with process condition, enviromental approaches and high efectivenes of the technology.

Nowadays there are /important methods of material cutting based on the energy jet technologies, therefore they ensure better cutting quality, lower consumption of energy and increasing of cutting power. The technology water jet does not create dusty environment. Also it does not thermally influenced on the cutting area and there is not occurred the material deformation during the cutting operations. The great advantage of water jet technology is the method of cold cut. This modern technology is introduced in all produced and industry branches at the present days. The reason, why we started to solve the mention problem, was too small attention given to solving the influence of abrasive material and water flow on the width of cutting gap at hydroerosion operations.

MATERIALS AND METHOD

According to general practice, the hydroabrasive cutting is realized on the one cutting table with one cutting head at application of high-pressure pump with power output 50 Hp (water nozzle 0,35 mm, abrasive nozzle 1,1 mm and powder density $650\text{g}\cdot\text{min}^{-1}$).

Similarly, in the case of two cutting tables, there is classically used separately one cutting head, of which cutting powder output is dimensioned according to high-pressure pump power output. This cutting method was realised in the workplace of firm WATING Prešov, where the cutting heads were dimensioned according to variant I. The mark of cutting head is $D_w/D_a/P_w$, where D_w is inner diameter of water nozzle, D_a is inner diameter of abrasive nozzle and P_w means flow per minute.

Variant I : 1. Table - Head 0,35/1,02/3,25 and 2. Table - Head 0,35/1,02/3,25

In the case of dividing of water jet on application of two cutting heads simultaneously on one or two cutting tables, it is possible to combine the cutting heads in variants by mode, as it recommends the producer of technology.

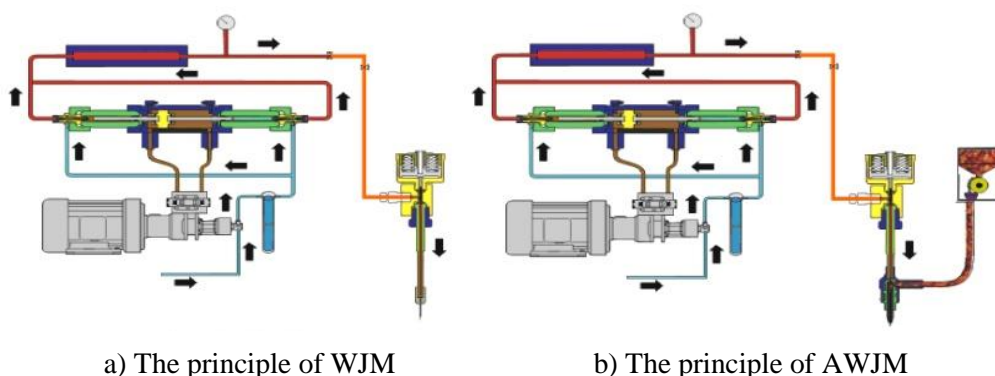
The dividing of water jet was made out of accord with producer recommendation for cutting with two cutting heads on the both tables simultaneously in the firm WATING Prešov. There were used combination of various water nozzle to abrasive nozzle with the inner diameter 0,76 mm according to variant 1 to 3.

Variant 1 : 1. Table - Head 0,20/0,76/1,05 / 2. Table - Head 0,25/0,76/1,65

Variant 2 : 1. Table - Head 0,20/0,76/1,05 / 2. Table - Head 0,30/0,76/2,37

Variant 3 : 1. Table - Head 0,25/0,76/1,65 / 2. Table - Head 0,25/0,76/1,65

The centre of high-pressure cutting equipment is high-pressure pump, pump with pressure converter multiplier with oil-hydraulic drive and pressure accumulator. The pressure of water is brought by high-pressure pipe to cutting head, which is controlled by electro-pneumatic valve. The principle of water jet cutting is shown in the Fig.1.



a) The principle of WJM

b) The principle of AWJM

Figure 1: The principle of water jet cutting - hydroerosion jet

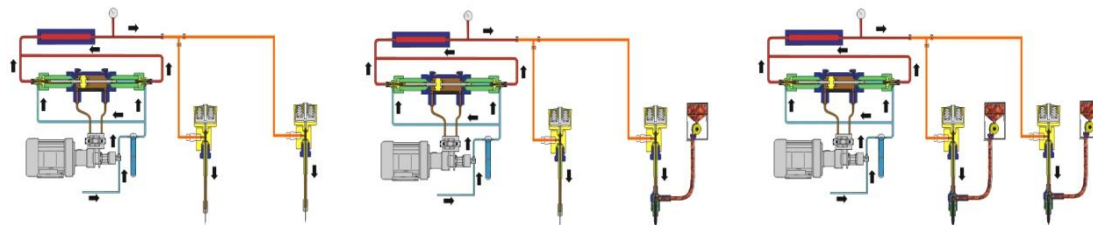
Subsequently, in the Fig. 2 are shown the models with dividing of high-pressure into two cutting heads, it means cutting with two heads simultaneously.

We can create models of water jet dividing as:

a) Model of KMWJ-WW – utilises the principle of WJM + WJM

b) Model of KMWJ-WA – utilises the principle of WJM + AWJM

c) Model of KMWJ-AA – utilises the principle of AWJM + AWJM



a) Model of KMWJ-WW

b) Model of KMWJ-WA

c) Model of KMWJ-AA

Figure 2: Models of water jet dividing into two heads

For experimental research were determined working pressure 300 MPa and according to Tab. 1, there were determined the quantity of water flow per minute, which was evaluated on the base of table processing of pressure and flow, given by firm Flow Systems and KMT.

Table1: The rate of water nozzle to abrasive nozzle with determination of water flow at the pressure 300 MPa

The rate of water nozzle to abrasive nozzle with determination of flow of high pressure water	Water nozzle and flow		Abrasive nozzle (Dimension of inner diameter of nozzle) [mm]
	Dimension of inner diameter [mm]	Flow of high pressure water [l]	
0,20/0,76/1,05	0,20	1,05	0,76
0,25/0,76/1,65	0,25	1,65	0,76
0,30/1,1/2,37	0,30	2,37	1,1 ; (0,9 ; 1,02)
0,35/1,1/3,25	0,35	3,25	1,1 ; (0,9 ; 1,02)

The research was realized in the firm WATING Prešov, s.r.o.(Ltd), where classically on the two working tables are used by one cutting head, which cutting power was dimensioned according to Tab.1 as one of solving variants. The research goes out from the concrete condition of working place of firm WATING Prešov, s.r.o., in configuration one high- pressure pump and two CNC XY tables, see Fig. 3.

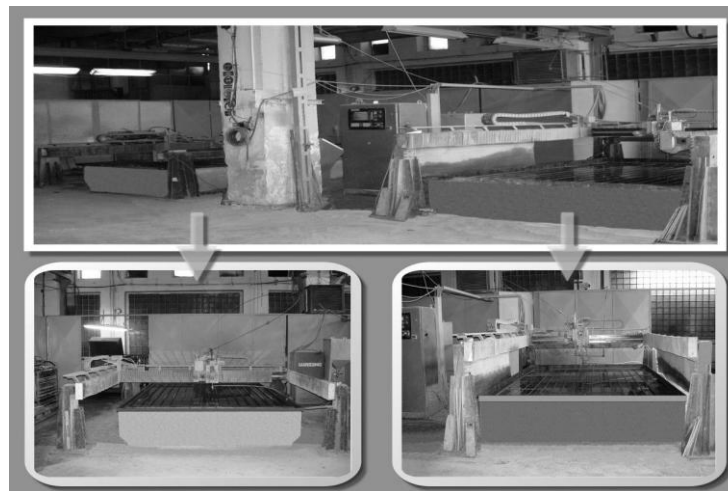


Figure 3: The workplace of JOB SHOP of firm Wating Prešov, s.r.o. in Prešov

According to mentioned combinations of high pressure water flow and rates of combinations of abrasive focusing nozzle to water nozzle, there were proposed the shapes of testing samples. On the samples were evaluated parameters, which are important to practice. The proposal of testing sample with illustration of cutting direction is shown in the Fig. 4

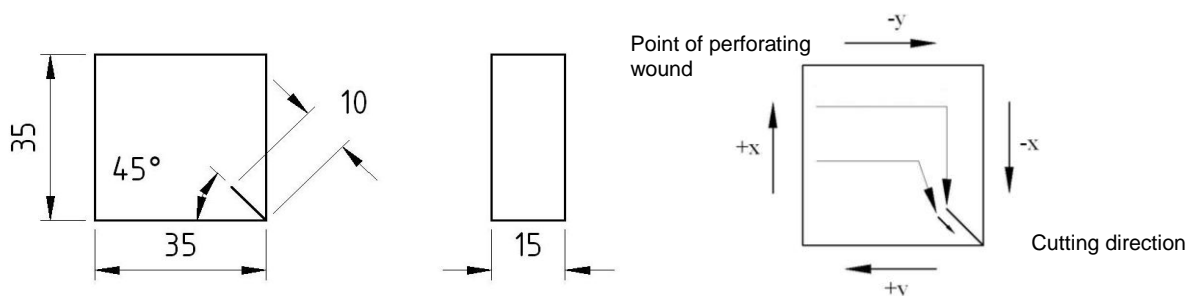


Figure 4: The testing sample with determination of cutting direction

The material of testing samples for experimental research was according to standard STN 417240, class 17 240, AISI 304. This material was chosen from the reason of using of these materials in the firm WATING Prešov, s.r.o., where the cutting operations were largely made from the anti-corrosive material AISI 304 in the volume approximately 85 % of monthly production.

For the definition of parameters of cutting samples, Tab.2, there were determined constant, variable parameters and also were defined measured parameters on the cutting samples, which were evaluated. In the Fig. 5 is shown the cutting of experimental samples.

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Table 2: The parameters of testing samples – constant, variable and evaluated ones

Constant parameters	
Dimension of sample	35 x 35 x 35 x 35 mm
Cutting direction	+Y; +X; -Y; -X (in the clock direction)
Cutting longitude for evaluating of cutting gap	10 mm
Type of material	Sheet AISI 304 *Austenitic rustless* 17 240* W.Nr. 1.4301
Material width	8 mm; 15 mm; 30 mm
Longitude of cut	35 mm for 1 edge and rate/speed
Water pressure	300 MPa
The angle of jet impact on material	90° perpendicularly on material
Type of abrasive material	BENGAL BAY GARNET
Abrasive Mesh	# 80
Variable parameters	
Cutting speed	50; 75; 100; 125 mm/min
Quantity of abrasive material	100; 150; 200; 250 g/min
Water nozzle	0,20; 0,25; 0,30; 0,35 mm
Abrasive nozzle	0,76; 1,02 mm
Flow of high-pressure water	1,05; 1,65; 2,37; 3,25 l/min
Distance nozzle above material	3; 5 mm
Evaluated parameters	
Input/Output of jet into/from material	mm
Roughness of cutting area Ra	μm



Figure 5: The cutting of experimental samples

ANALYSIS AND EVALUATION OF RESEARCH RESULTS

The cutting samples were evaluated on the each cutting area by help of contact measuring instrument Surftest SJ-301 Mitutoyo, we measured the values of roughness Ra and Rz. The measurement of roughness of particular areas of samples were made in the middle cutting area on the distance 12,5 mm.

In the Fig. 6 is shown the sequence of cutting of each sample area , from the right side to left side, it means from „ 43.1a“ to „43.1d“, whereby on the each side of sample were changed the cutting parameters.

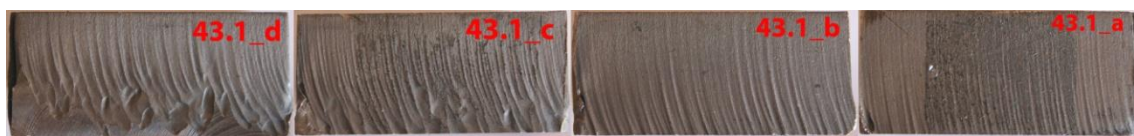


Figure 6: The cutting area of sample 43.1 – cutting direction 43.1a, 43.1b, 43.1c, 43.1d

The following Fig. 7 shows the view of the cutting gap again in the direction from the right side to left side, and it is the view on the sample upper, lower and front ones.



Figure 7: The cutting gap of the sample 43.1 – view form the right to left upper, lower and front ones

The measured values of the roughness of mentioned samples are shown in Fig.8.

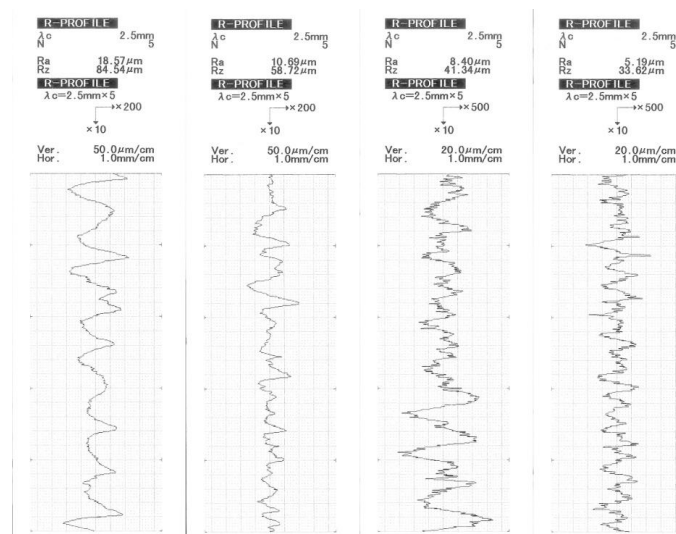


Figure 8: The roughness values of tested samples

The dimension/size of cutting gap was measured in three measured points from the upper and lower views by digital measuring accuracy instrument.

The Figure 9 shows the database of measured and evaluated experimental samples of material with thickness 8 mm.

Similarly, there were experimental researched also the various thicknesses of the same material. There were measured thickness of material 15 mm and 30 mm .

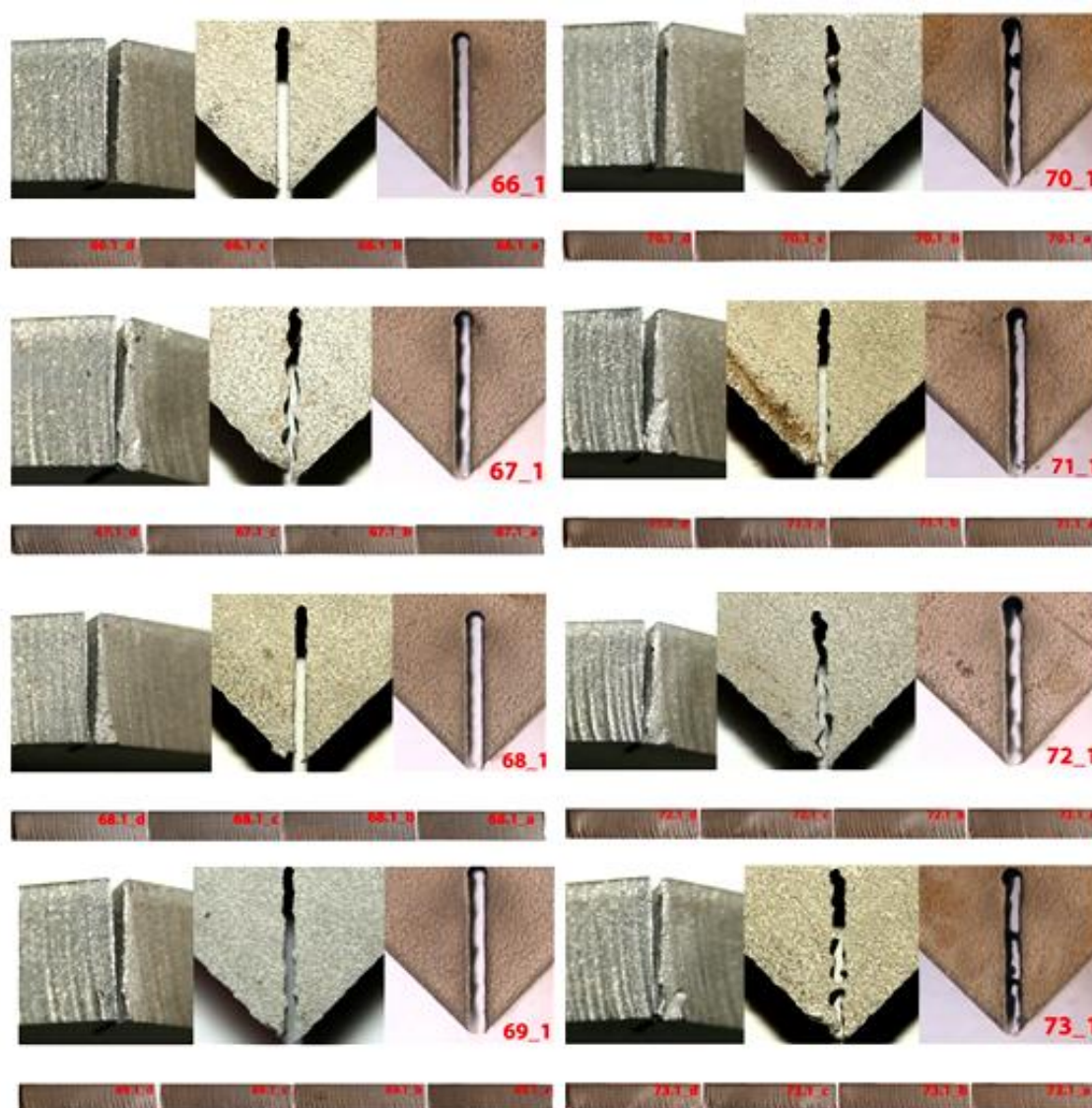


Figure 9: The database of the catalogue of measured and evaluated samples

DISCUSSION

The graphic dependences of gap width from the quantity of abrasive material and water flow are mentioned in Fig. 10 and Fig. 11.

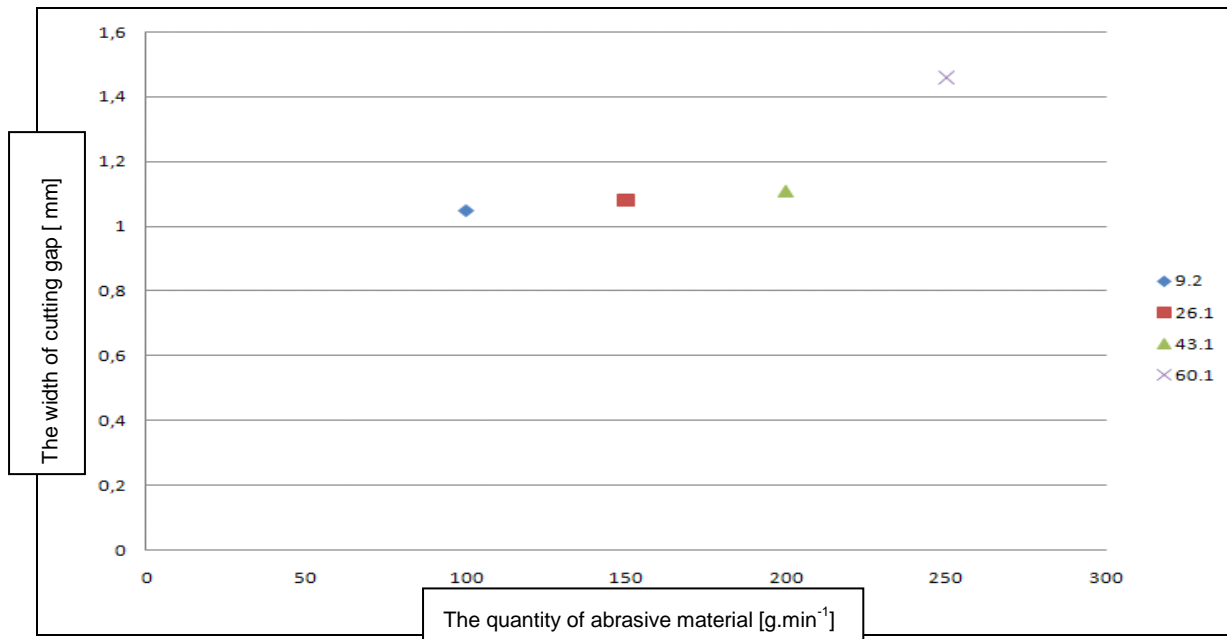


Figure 10: The dependence of gap width from the quantity of abrasive material

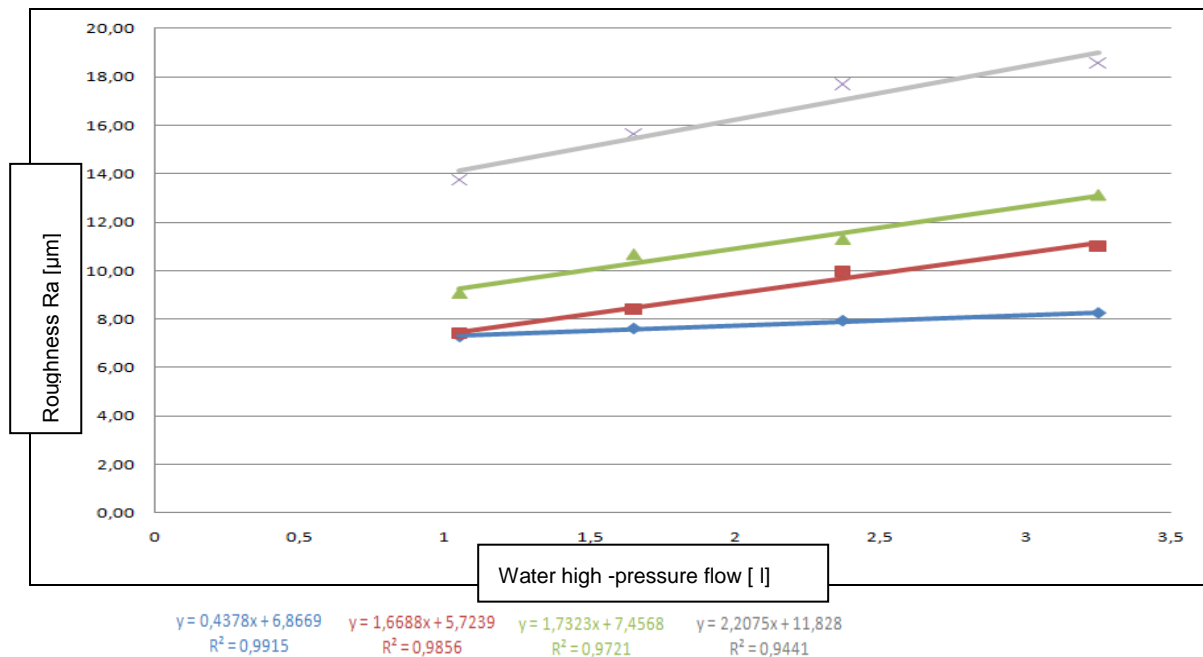


Figure 11: The dependence of roughness from the water flow

- ◆ The cutting speed 50mm.min⁻¹,
 ■ The cutting speed 75mm.min⁻¹,
 ▲ The cutting speed 100mm.min⁻¹,
 ✕ The cutting speed 125mm.min⁻¹

The evaluation of samples goes out from the achieved and registered dates which are defined in the tables. There is shown in the tables the changes of parameters in dependence from the quantity of abrasive material, water flow and their influence on the thickness of water jet, the gap thickness and also the quality of cutting area.

According to obtained results we can make a conclusion:

- Increasing of quantity of abrasive material makes increasing the cutting gap,
- Increasing of quantity of abrasive material makes worse the roughness of cutting area,
- Increasing of the water flow makes worse the roughness of cutting area,
- Increasing of cutting speed makes worse the quality of cutting area.

CONCLUSIONS



From the measured and observed dates we can make the conclusion that the quality of the cutting gap is influenced by all three parameters. If we want to keep the cutting quality and we increase the cutting speed, it is also necessary to increase the quantity of abrasive material in the water jet.

With the increasing of quantity of abrasive material the cutting gap is enlarge and also the values of roughness of cutting area are increasing. At lower or deficient quantity of abrasive material it can happened that the cut in testing material will be not completed. The material will be wasted or it will be necessary to machine whereby the production costs are increasing and also the production time for whole processing is increasing. The optimal combination of cutting speed, water flow and quantity of abrasive material enable/allow to shortage the cutting time at the reaching of quality of cutting area and to guarantee the higher satisfaction at the usage of this technology.

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REFERENCES

- [1] Vasilko, K. ; Kmec, J. : *DELENIE MATERIÁLU*, DATAPRESS, ISBN 80-7099-903-9, Prešov, (2003)
- [2] Kmec, J. & Sobotová, L.: *PROGRESÍVNE DELENIE HYDROERÓZIOU*, In: *Strojírenská technologie - Plzeň 2011: IV ročník mezinárodní konference* , ZČU v Plzni, Česká republika, 25. - 26.1.2011, pp.1-6, ISBN 978-80-7043-934-0,Plzeň, (2011)
- [3] Badida, M. ; Majerník, M. ; Šebo, D. & Hodolič, J. : *STROJÁRSKA VÝROBA A ŽIVOTNÉ PROSTREDIE*, Viena, ISBN 80-7099-695-1,Košice, (2001)
- [4] Kmec, J. & Sobotová, L.: *DELENIE HYDROERÓZNEHO LÚČA*, In: *Trendy a inovatívne prístupy v podnikových procesoch: 12. medzinárodná vedecká konferencia*, pp. 1-5, ISBN 978-80-553-0330-7, TU SjF Košice, december 2009, Košice, (2009)
- [5] Kmec, J. & Sobotová, L.: *VODNÝ LÚČ 25 ROKOV NA SLOVENSKU*, In: *Transfer Inovácií*, Vol.10, (2010), NO.18, pp.160-164, ISSN 1337-7094
- [6] Kmec, J., Sobotová, L. & Bičejová, L.: *KATEGÓRIE FAKTOROV VPLYVAJÚCICH NA HYDROERÓZIU*, In: *Trendy a inovatívne prístupy v podnikových procesoch: 13. Medzinárodná vedecká konferencia*, pp. 1-10, ISBN ISBN 978-80-553-0570-7, TU SjF Košice, 8.12.2010, Košice, (2010)
- [7] Kmec J. : *SKÚSENOSTI S AUTOMATIZÁCIOU PROCESU DELENIA MATERIÁLOV NOVÝMI TECHNOLOGIAMI*, In.: *1. medzinárodný seminár IDEE 9*, pp.1-6, Trenčín, (1994)
- [8] Kollárová, M. & Kmec, J. : *ANALYSIS OF ENVIROMENTAL SYSTEM FOR RECYCLING ABRASIVE MATERIAL USED IN WATERJET CUTTING*, In: *11th Conference on Environment and Minereal Processing – Part III*, Ostrava 2007, pp. 227-230, ISBN 978-80-248-1431-5, Ostrava, (2007)
- [9] Hloch, S. & Fabian, S. : *MODELING OF ABRASIVE WATERJET CUTTING PROCESS BY MEANS OF FULL FACTORIAL DESIGN*, In.: *The 47th Conference on Simulation and*

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Modeling, Helsinki, September 2006, Helsinki, Suomi, (2006)

[10] Badida, M. ; Muránsky, J. & Hricová, B.: *EKODIZAJN V STROJÁRSTVE*, ELFA, s.r.o., ISBN 978-80-553-0788-6, Košice, (2011)

[11] Muránsky, J. ; Badida, M.: *TRVALO UDRŽATELNÝ ROZVOJ V STROJÁRSTVE*, Viena, ISBN 80-7099-519-X, Košice, (2000)

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