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APPLICATION OF WATER JET FOR CUTTING POLYMER MATERIALS

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Preliminary Note – Prethodno priopćenje

Due to the nature of polymeric materials, during thermal cutting processes it leads to their melting, and therefore appear errors in the final product. This paper presents a "cold" process of cutting polyamide 6 ie . SIPAS 60, where there are given the characteristics of materials and guidelines for satisfactory quality of process. The authors made the cut experiment 3^2 were they changed the cutting parameters (cutting pressure, cutting feed and abrasive mass flow); the surface roughness was measured by the depth of material, because the roughness changes with the thickness of the material to be cut.

Key words: polimer material (PAG), water jet cutting, PA6, cutting parameters

INTRODUCTION

The material we used for the experiment is polyamide 6 ie. SIPAS 60. From Table 1 we can see that the melting temperature of SIPAS 60 is 220 °C, which makes it unsuitable for cutting with some of the thermal processes (laser) or saw cutting, because of build up edge. Because of this problem, during the production, place in the production process has found a water jet cutting, so-called cold process of cutting material.

In water jet cutting, there is no heat generated. This is especially useful for cutting tool steel and other metals where excessive heat may change the properties of the material.

Unlike machining or grinding, water jet cutting does not produce any dust or particles that are harmful if inhaled.

The kerfs width in water jet cutting is very small, and very little material is wasted.

Water jet cutting can be easily automated for production use.

Water jets are much lighter than equivalent laser cutters, even when mounted on an automated robot. This reduces the problems of accelerating and decelerating the robot head, as well as taking less energy. [1]

But this procedure has its disadvantages, some of the disadvantages are the jet lag and poor quality of the machined surface on the lower section, ie. meaning the place where the stream emerges from the cutting zone. Therefore, we conducted an experiment where we changed the cutting parameters to get the satisfactory quality of the machined surface. Surface roughness was measured with a Mitutoyo device Surf test SJ301 on upper, middle and in lower zone cut.

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PROPERTIES OF THE MATERIAL FOR MACHINING

SIPAS 60 is a material with excellent resistance to abrasion and impact load. It is used for making gears, coupling elements for eccentricity, sealing rings, screw elements, sliding elements and other elements exposed to impact loads. Because of its uses, specific materials, and due to demand of accuracy and product quality, selection of parameters and regimes of machining was essential for the proper and undisturbed work of the product and manufacturing process.

Table 1 **Mechanical properties of the cut material [2]**

Typical values at 23 °C	Values
Properties	
Abbreviated term	PA6
Density	1,14 / g/cm³
Viscosity number	140 / ml/g
Processing	
Melting temperature	220 / °C
Mechanical properties	
Tensile modulus	3,900 / MPa
Yield stress	90 / MPa
Flexural modulus	2,900 / MPa
Flexural strength	95 / MPa
Ball indentation hardness	190 / MPa

The maximum temperature that develops in water jet cutting is 70 - 80 °C. The temperature is much lower than the melting temperature of material which we used for cutting.

USED MACHINE FOR EXPERIMENTAL WORK

In AWJ machining, the work piece material is removed by the action of high-speed water mixed with abrasive particles. A high-speed water jet transfers kinetic energy to the abrasive particles and the mixture impinges on to the work piece. On Figure 1 can be seen machine with which is cut SIPAS 60. Working dimensions are 3 000 x 2 000 mm. The maximum oil pressure in the cylinder is 21 MPa. Maximum pressure of water is 420 MPa. Table 2 shows maximal recommended thickness (for this cutting machine) of material for cutting, for different material.

PROBLEMS DURING THE CUTTING

Some of the disadvantages of water jet cutting are the jet lag and poor quality of the machined surface on the lower section, ie. meaning the place where the stream emerges from the cutting zone.

In lower section of cut material on Figure 2 (Rough zone) water stream do not have enough strength for good material cutting. The reason for this is insufficient amount of kinetic energy of water stream.

The result of this hydro-mechanical cutting process depends on a large number of process factors such as water pressure, orifice diameter, standoff distance, abrasive and material feed rate etc.

Table 2 **Maximum thickness of material**

Cutting material		Thickness of material / mm
1	Inox	70
2	Wood	150
3	Glass	50
4	Ceramics	30
5	Polymer	130
6	Stone	90
7	Copper	80
8	Aluminium	100
9	Steel	100

Figure 1 Used machine for water jet cutting - TENKING 23020

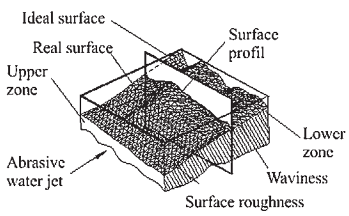


Figure 2 The profile of surface created by abrasive water jet [3]

The shape of the cutting jet stream is also very important. The evaluation of the quality of machined surface is based on the judgment of its roughness. Theoretical roughness depends exclusively on AWJ tool geometry and applied process of machining whereas a real roughness appears as the result of theoretical roughness though with bigger or lesser occasional roughness provoked by the many factors. [4] These factors create surface like trajectory area for working movement of AWJ tool (Figure 3).

EXPERIMENTAL WORK

Plan of experiment is shown at Figure 3 and Table 3. For this experimental work, we changed abrasive mass flow, cutting head velocity and water pressure. A combination of different cutting factors, water pressure, cut-

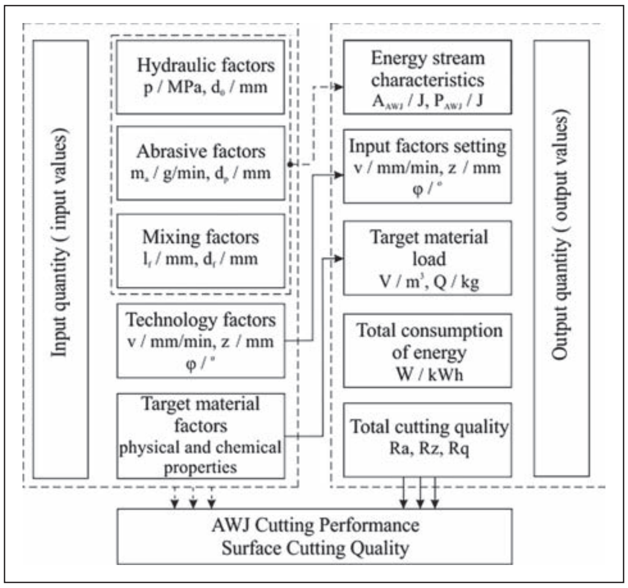


Figure 3 Conceptual structure and relationship of factors vs. parameters proposal [3]

Table 3 **Parameters of cutting**

Mass flow Kg/min	Pressure / MPa	Cutting head velocity / mm/min	
1,25	350	80	A1
		120	A2
		160	A3
	300	80	B1
		120	B2
		160	B3
	250	80	C1
		120	C2
		160	C3
2	350	80	D1
		120	D2
		160	D3
	300	80	E1
		120	E2
		160	E3
	250	80	F1
		120	F2
		160	F3

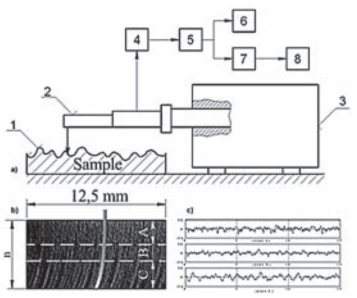


Figure 4 Contact profilometer scheme of Mitutoyo SJ301, (1 – measured sample, 2 – measurement head with profile follower, 3 – feed mechanism, 4 – amplifier, 5 – filter, 6 – registration unit, 7 – signal processing unit, 8 – display unit) [3]

Table 4 Parameters of contact profilometer for measurement roughness

STAND	JIS 2001
PROFILE	R
EVA-L	12,5 mm
N	5
λ_c	2,5 mm
M - SPEED	0,5 mm/s

ting head velocity, abrasive grain size, abrasive mass flow we can obtain a satisfactory quality of the cut surface. Therefore, further work will change grain size.

MEASURE SURFACE ROUGHNESS

For measuring surface roughness we used contact process of measure with Mitutoyo SJ301 Surf test with measure parameters from Table 4. Figure 4 describes theoretical process of measuring surface roughness. Figure 5 shows measuring surface roughness after cutting material.

RESULTS OF SURFACE ROUGHNESS MEASURE

If one looks at parameters for cutting in Table 2, the expected worst results will be on sample C3, because sample C3 has the smallest abrasive mass flow (1,25 kg/min), the smallest pressure (250 MPa) and the largest cutting head velocity(160 mm/min). Cutting material has 20 mm thickness. Figure 6 and Table 5 show results

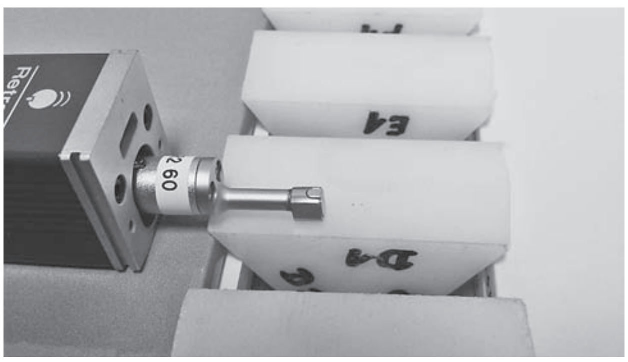
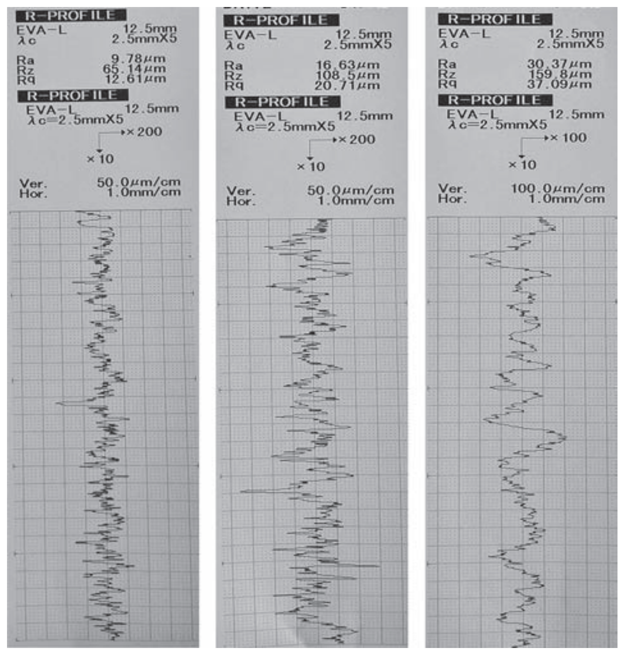


Figure 5 Measurement of roughness

Table 5 **Results of measurements**

Measure depth / Number	Roughness / μm					
	1 / mm		11 / mm		19 / mm	
	Ra	Rz	Ra	Rz	Ra	Rz
A1	9,1	59,1	10,6	69	11,5	87
A2	8,5	61,9	12	72	13	82,5
A3	9,3	75	12,3	81	17	120
B1	9,5	64	10,8	74	12,2	80
B2	8,9	65	12	90	15,2	99
B3	10	29	15,5	109	18	112
C1	9,5	65,5	11,5	75	20	109
C2	9,7	68	16	93	24,5	143
C3	9,8	73	17	108	30	160
D1	7,1	64	8,8	74	9,5	75
D2	7,5	68,5	8,9	69	12,5	77
D3	7,8	74	9	77	13	78
E1	8,5	66	9	69	11	87
E2	9	64	11	77	12	90
E3	9	62	12	88	13	97
F1	8	68	8,5	74	10,5	75
F2	9,5	91	10	88	13	113
F3	8,2	60	10,5	90	15	103



a) b) c)

Figure 6 Sample C3 roughness from Table 4 1 mm depth, b) 11 mm depth, c) 19 mm depth

of measurements C3 in upper (1 mm of depth), middle (11 mm of depth) and in the lower (19 mm of depth) zone of cut.

If we compare results of roughness measurements in lower zone cut C3 and F3 with similar parameters (pressure and cutting head velocity), but different mass flow can be concluded that for increased mass flow of 75 %, we get 50 % better surface roughness. For increased water pressure from 250 MPa to 350 MPa with similar mass flow and cutting head velocity (sample A1 and C1), in lower zone of cut surface, we get 20 % better surface roughness. In upper and middle zone with changing cutting parameters we have impact on surface roughness only by 10 %. If we have small thickness material, it can be cut with smaller pressure, smaller cutting head velocity and can save machine and increase profit.

CONCLUSIONS

Thickness of material has a very big impact on the surface roughness. In lower section of cut material (Rough zone) water stream do not have enough strength for good cutting of material. The reason for this is insufficient amount of kinetic energy of water stream.

Because of this, authors recommend increase of water pressure or decrease of cutting head velocity.

During the analysis, by changing cutting parameters (increased water pressure and abrasive mass) it has impact on the surface roughness. The increase of abrasive mass flow has a bigger impact than the increase of water pressure. One of the reasons is a small step water pressure increase by 50 MPa.

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