Study of Surface Roughness for Steel Parts Cut with Abrasive Water Jets

PhD. Eng **Sandor RAVAI-NAGY[1],** PhD. Eng. **Nicolae MEDAN**[2]

[1]Technical University of Cluj-Napoca, North University Center Baia Mare,
Ravai.Nagy.Sandor@cunbm.utcluj.ro

[2]Nicolae.Medan@cunbm.utcluj.ro

Abstract: *Today, abrasive water jet technology is used into a full scale production process such us contour cutting, drilling, milling, turning, threading. The purpose of this paper is to determine the surface roughness for two type of steel (S235JR and S355JO) cutting with abrasive water jet (AWJ) cutting machine - Bystronic ByJet Pro L, varying the traverse speed and abrasive flow rate parameters.*

Keywords: *Abrasive water jet, surface roughness, contour cutting*

1. Introduction

First water jet cutting machines was used in the1970s for cutting wood and plastics material [3] and first abrasive water jet cutting machine was commercialized in 1980s, when was considering as a pioneer in the area of unconventional processing technologies [6]. Today, abrasive water jet technology is used into a full scale production process such us contour cutting, drilling, milling, turning, threading, cleaning. Abrasive water jet machines is used in the processing of different type of materials such as titanium, steel, brass, aluminium, stone, glass and composites [2].
In abrasive water jet process, the work piece material is removed by the action of a high-velocity jet of water mixed with abrasive particles based on the principle of erosion of the material upon which the water jet hits [5]. Abrasive water jet machining has few advantages such as high machining versatility, small cutting forces, high flexibility and no thermal distortion [1].
An abrasive water jet is a jet of water that contains some abrasive material like: aluminium oxide, silicon carbide, sodium bicarbonate, dolomite and/or glass beads with varying grain sizes.
The main parts of any abrasive water jet cutting machine are: the hydraulic pump, which provides pressured water, an amplifier, in which the pressure of water is increased and the cutting head, where the water is mixed with abrasive from the system [4].

2. Experiment setup

2.1 The abrasive water jet cutting machine

The experiments were conducted using an abrasive water jet (AWJ) cutting machine - Bystronic ByJet Pro L, presented in Figure 1.

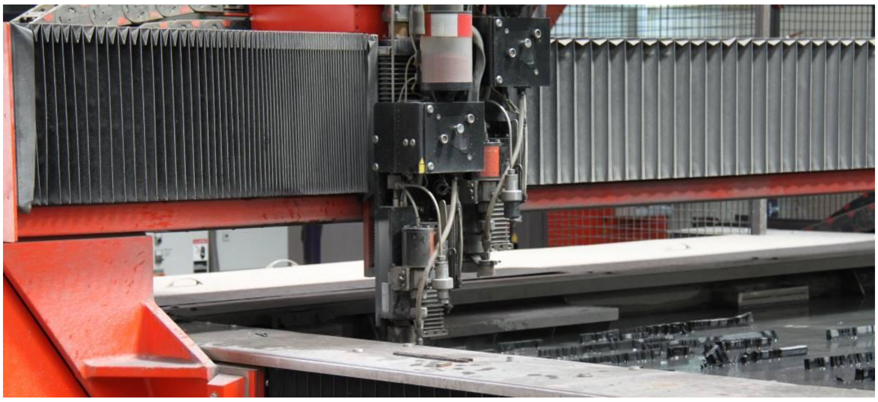

Fig. 1. Abrasive water jet cutting machine used: Bystronic ByJet Pro L

This abrasive water jet (AWJ) cutting machine is a computer controlled machine (CNC).

2.2 Type of material and geometry for cutting parts

Were used for cutting contour two types of steel for general use: S235JR and S355JO.
The design of obtain pieces is presented in figure 2. It was realized two pieces, one for each type of material. The thickness of the pieces is 10 mm.

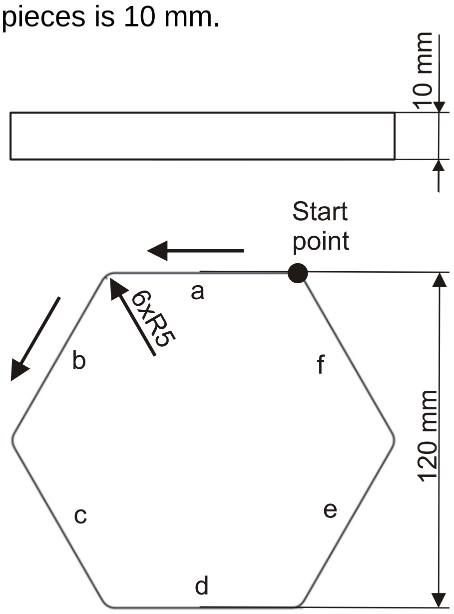

Fig. 2. Design of cutting pieces and order of cutting for established process parameters

2.2 Setting up the process parameters

To cut pieces were used the values of process parameters presented in table 1.

TABLE 1: Process parameters.

Processing regime	Position on piece	Water jet pressure [bar]	Traverse speed [mm/min]	Abrasive flow rate [g/min]
1	a	3600	213	342
2	b		112	342
3	c		260	342
4	d		254	600
5	e		132	600
6	f		312	600

For each face of the hexagon corresponding a certain set of the parameters (corresponding with the values define in table 1). For each fillet zone it was changed the processing regime.
The abrasive material used was GMA Garnet 80 Mesh (300 - 150μm). This type of granulation is recommended to standard industrial applications. Interior diameter of sapphire nozzle was 0.28 mm.

2.3 Achievement the measurements

After cutting the pieces, was measurement the roughness R_a for each face of the pieces.
For each side of the hexagonal pieces was made measurements of surface roughness from two directions, one perpendicular to the direction of displacement of the cutting water jet and one parallel to the direction of displacement of the cutting water jet. For each direction were established three lines of measurements evenly distributed along the length and width respectively cutting surfaces (figure 3).
The device used to measure the surface roughness was Time Group Inc. TR200.

To get the value of surface roughness was measured that roughness on a length of four mm for each area measurement (according to the methodology of measurement established in measurement scheme shown in figure 3). In this way they were obtained six values of surface roughness R_a for each side of machined pieces.

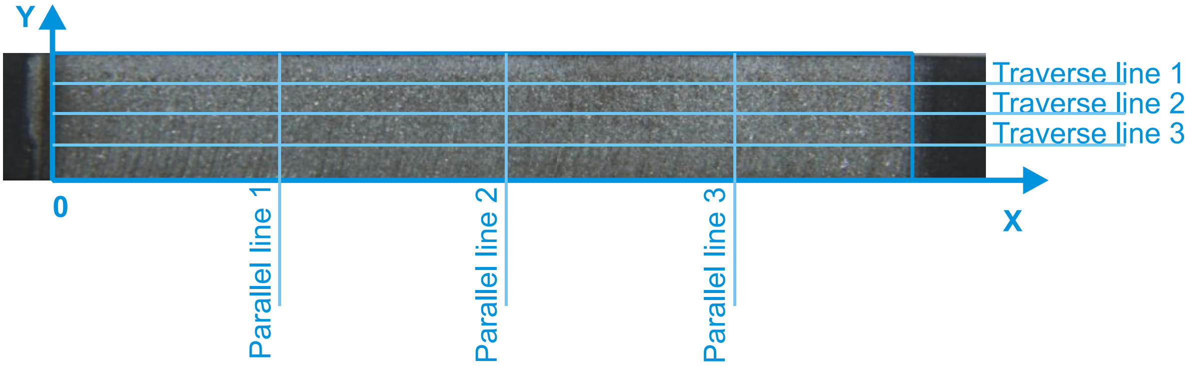

Fig. 3. The scheme of the measurements for each side of the pieces

3. Results

In the following are presented the values obtained for surface roughness corresponding to the two types of materials used and for the six process parameters used (table 1).

3.1 Values of surfaces roughness for S235JR steel piece

In the table 2 are presented the values of roughness surfaces for direction perpendicular to the cutting direction.

TABLE 2: Results of surface roughness R_a perpendicular to the cutting direction for S235JR material.

Measured position on face	Processing regime					
	1	2	3	4	5	6
	Position on piece					
	a	b	c	d	e	f
	Surface roughness Ra [µm]					
Traverse line 1	4.026	3.677	4.175	3.155	2.624	2.768
Traverse line 2	4.371	3.814	6.224	3.682	2.736	4.984
Traverse line 3	6.154	3.496	9.973	6.634	2.810	5.165

In the table 3 are presented the values of surfaces roughness for direction parallel to the cutting direction.

TABLE 3: Results of surface roughness R_a parallel to the cutting direction for S235JR material.

Measured position on face	Processing regime					
	1	2	3	4	5	6
	Position on piece					
	a	b	c	d	e	f
	Surface roughness Ra [µm]					
Parallel line 1	3.234	2.732	3.587	2.957	2.496	3.252
Paralle line 2	2.972	2.380	4.051	3.144	2.423	2.695
Paralle line 3	2.187	2.595	3.177	3.071	3.106	3.214

On the basis of values obtained from tables 2 and 3 of the surfaces roughness value achieved by the graphs of the two directions for S235JR material, graphs shown in figures 4 and 5.

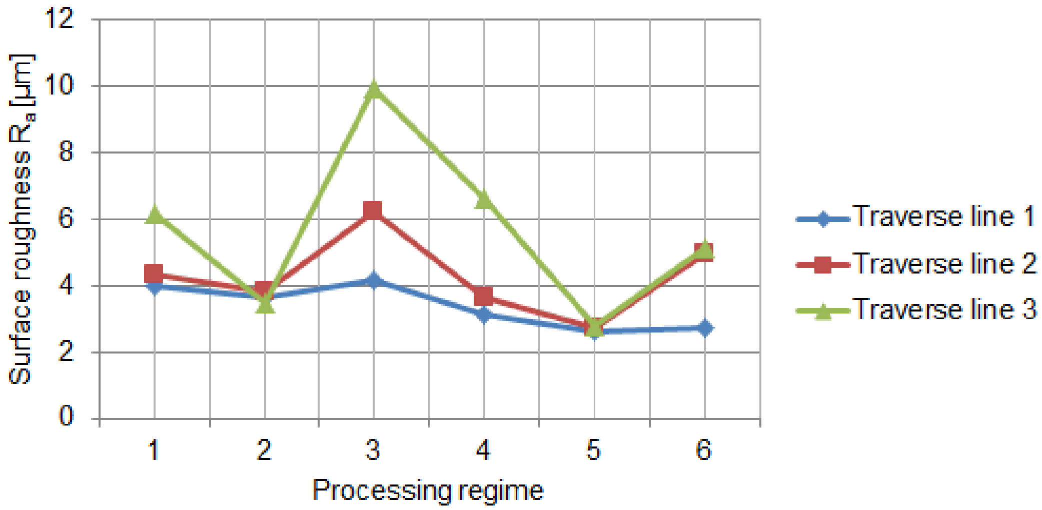

Fig. 4. Surfaces roughness Ra [µm] for perpendicular direction for S235JR steel

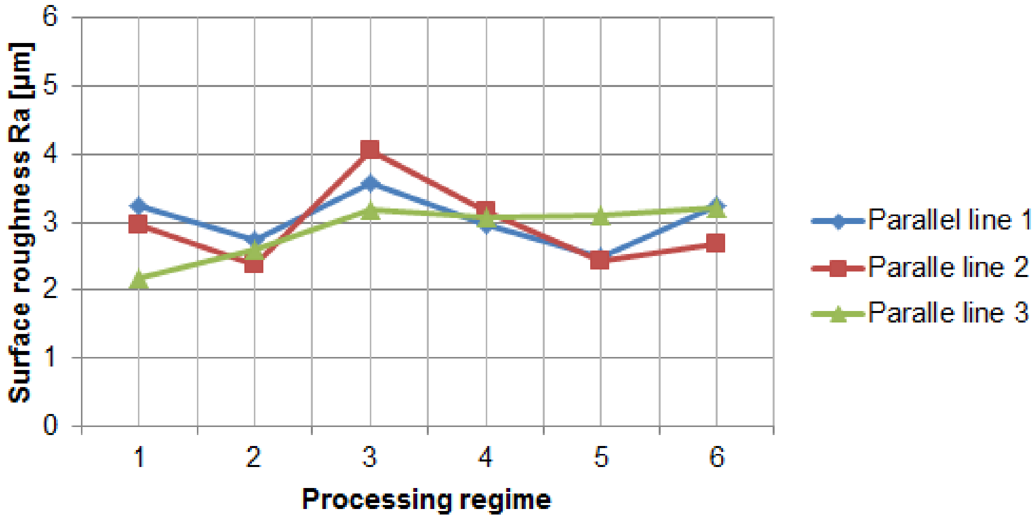

Fig. 5. Surfaces roughness Ra [µm] for parallel direction for S235JR steel

3.2 Values of roughness surfaces for S355JO steel piece

In the table 4 are presented the values of roughness surfaces for direction perpendicular to the cutting directions.

TABLE 4: Results of surface roughness R_a perpendicular to the cutting direction for S355JO material.

Measured position on face	Processing regime					
	1	2	3	4	5	6
	Position on piece					
	a	b	c	d	e	f
	Surface roughness Ra [µm]					
Traverse line 1	3.966	2.735	3.024	3.558	2.652	3.275
Traverse line 2	4.520	3.136	3.773	4.957	3.905	3.629
Traverse line 3	5.317	4.318	6.254	9.061	2.795	6.958

In the table 5 are presented the values of roughness surfaces for direction parallel to the cutting directions.

TABLE 5: Results of surface roughness R_a parallel to the cutting direction for S355JO material.

Measured position on face	Processing regime					
	1	2	3	4	5	6
	Position on piece					
	a	b	c	d	e	f
	Surface roughness Ra [µm]					
Parallel line 1	3.086	1.819	1.274	3.015	2.052	3.111
Parallel line 2	2.887	2.909	1.638	2.655	2.224	3.172
Parallel line 3	2.407	2.368	1.573	3.195	2.178	3.147

On the basis of values obtained from Tables 4 and 5 of the surfaces roughness value achieved by the graphs of the two directions for S355JO material, graphs shown in Figures 6 and 7.

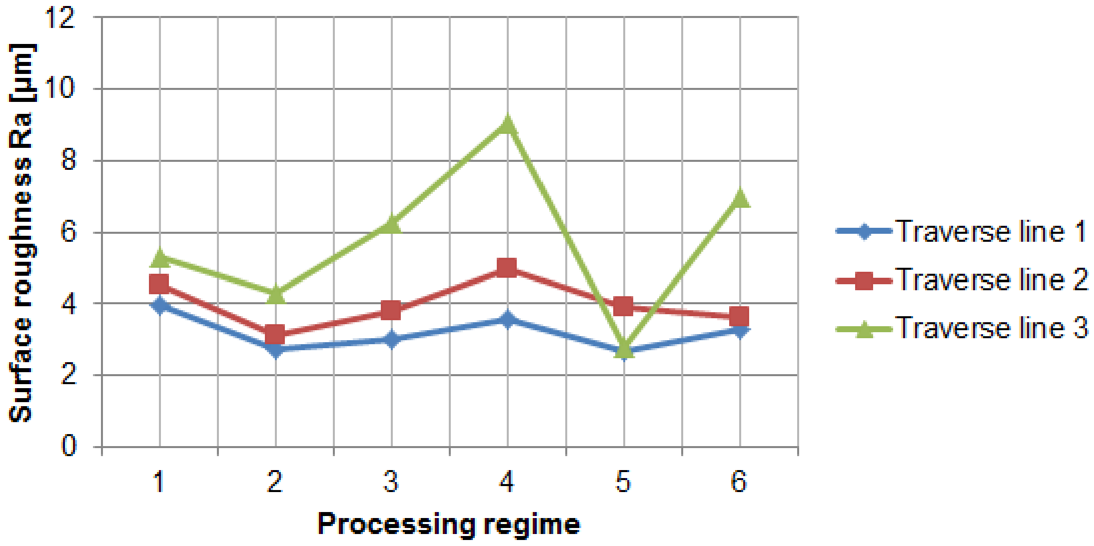

Fig. 6. Surfaces roughness R_a [µm] for perpendicular direction for S355JO steel

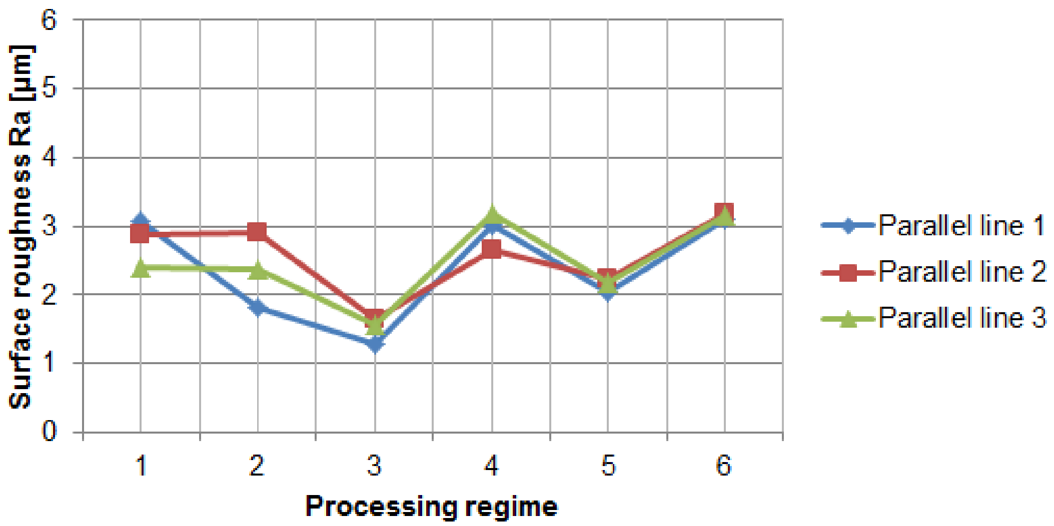

Fig. 7. Surfaces roughness R_a [µm] for parallel direction for S355JO steel

3. Conclusions

In this work was measured surface roughness R_a obtained after cutting contour for two types of steel for general use: S235JR and S355JO. Contour cutting was performed using an abrasive water jet cutting machine Bystronic ByJet ProL. For each type of material was cut one piece that has six sides. For each side was used a different processing regime.
Process parameters that have been modified are traverse speed and abrasive flow rate. Water jet pressure was fixed at 3600 bar. The abrasive material used was Garnet 80 mesh (300-150 µm).
The values of surface roughness R_a depends by:

1) Type of steel used. For S355JO steel the values of surface roughness are lower than S235JR steel. This is because the chemical composition chemical composition of the two steels is different.
2) Values of process parameters. When the traverse speed is lower the values of surface roughness is lowers. When the abrasive flow rate is bigger the values of surface roughness is lowers. So, the values of surface roughness are directly proportional with the abrasive flow rate and inversely proportional with the traverse speed.
3) The place where the surface roughness is measured.
    a) The values of surface roughness are lower for traverse line 1 location and increase when the measurements are made for traverse line 2. The values are the biggest when the measurements are made for traverse line 3. This is because the energy of the abrasive water jet decreases with increasing the cutting depth.
    b) Considering the values of surface roughness for parallel lines measurements, the values are range between 1 µm to 4 µm. These values are not relevant considering the fact that measurements are made in the direction of cutting contour.

References

[1] U. Caydas, A. Hascalik, ”A study on surface roughness in abrasive waterjet machining process using artificial neural networks and regression analysis method”, 2008, ”Journal of Materials Processing Technology”, Volume 202, pp. 574–582;
[2] J. Kechagias, G. Petropoulos, N. Vaxevanidis, ”Application of Taguchi design for quality characterization of abrasive water jet machining of TRIP sheet steels”, 2012. ”The International Journal of Advanced Manufacturing Technology”, Volume 62, pp. 635–643;
[3] R. Kovacevic, M. Hashish, R. Mohan, M. Ramulu, T.J. Kim, E.S. Geskin, ”State of the art of research and development in abrasive waterjet machining”, 1997, ”Transactions of ASME. Journal of Manufacturing Science and Engineering”, Vol. 119, pp.765-785;
[4] I L. Marcu, C. Ciupan, S, ”Alternating Flow Hydraulic Generator for Water Jet Cutting Systems”, “Hidraulica” (No. 1/2016) Magazine of Hydraulics, Pneumatics, Tribology, Ecology, Sensorics, Mechatronics, ISSN 1453 – 7303, pp.61-66;
[5] K. Metin, K. Erdogan, E. Omer, ”Prediction of surface roughness in abrasive waterjet machining of particle reinforced MMCs using genetic expression programming”, 2011, ”The International Journal of Advanced Manufacturing Technology”, Volume 55, pp. 955–968;
[6] M.C. Selvan, N.M. Raju, H.K. Sachidananda,”Effects of process parameters on surface roughness in abrasive waterjet cutting of aluminum”, 2012, ”Frontiers of Mechanical Engineering” Volume7, Issue 4, pp. 439–444.