Journal of Polish CIMAC
Gdansk University of Technology
The Faculty of Ocean Engineering and Ship Technology

POSSIBILITIES OF SOME CONSTRUCTIONAL MATERIALS CUTTING BY MEANS OF WATER-ABRASIVE JET

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Abstract

In the paper results of comparative studies concerning the possibilities of cutting of some materials by means of the AWJM method were presented. Roughness parameters (very significant technological and operational factor) of surfaces after cutting were compared. Cutting was performed on the two materials' samples: quenched and tampered alloy steel (1.2080), and natural mineral material – syenite. Variable parameters in the cutting process were accepted: pressure of water-abrasive jet and feed rate. As a result of measurements involving selected roughness parameters (Ra, Rz and Rq). It was discovered that the tested quantities have a significant effect on the state of machined surfaces.

Keywords: *constructional material, abrasive-water jet machining (AWJM), machine building, civil engineering, roughness parameter*

1. Introduction

Cutting is operation very often existing in a lot of different manufacturing processes. These processes can be performed on a wide range of materials: from technical (metals, plastics) through mineral materials and derivative materials (rocks, ceramics) to biological materials (wood, straw, organic tissue) and a lot of industries, e.g.: machine building, civil engineering, extractive industry, shipbuilding industry.

Operations of cutting are applied at various stages of the production process and so the requirements concerning characteristics of cut surfaces are varied. different requirements will apply to cutting not followed by further operations or treatment and different – to cutting followed by further treatment.

Research presented in this paper involve a cutting method which uses a concentrated jet of water and abrasive material (AWJM) – the method that is developing rapidly due to its advantages [2, 4], but still defined as non-conventional treatment [7, 8].

The main aim of described experiments was to verify to what extent parameters of cutting using the AWJM method affect machined surface, especially its geometrical structure of elements made of material having very different features: steel, and natural mineral material. Surface roughness is one of the most important features of surface layer, therefore selected roughness parameters are taken as the measure for cutting results assessment.

2. Investigated object and range of experiments

Investigations concern samples with following geometrical features (*l* x *b* x *h*): 30x10x5 mm, made of different materials – metallic and mineral:

- very popular constructional steel, numbered 1.2080, symbol acc. to European Standard: X210Cr12, quenched and tampered to 43 HRC,
- syenite.

Used in investigations materials have strength feature and crystalline structure quite differ. Both of chosen materials are applied in machine-tools building, nevertheless, both for different units and elements. Tested steel is used for a lot of elements produce, e.g.: elements of machines, truss construction, and mineral material – for the machine body or table and as façade elements. The main reason of such choice was need to determine the some roughness parameters obtained by abrasive-water jet cutting with defined parameters.

Cutting operations were realized using abrasive-water contour machine, made of PR China marked DWJFB 1313. As independent variables in presented investigations following quantities were accepted:

- pressure of working fluid: p = 200, 250 MPa,
- feed rate: f = 64, 80 and 96 mm/min.

According to numerous references, e.g. [1, 3, 6], these factors essentially influences cutting surfaces features.

Fluid jet consists mixture of water and Garnet abrasive, mesh 80; nozzle diameter was 1.016 mm. During machining the cutting head was 2 mm from upper machined surface.

Results of cutting process were evaluated on the base of measurements of below mentioned three chosen roughness parameters:

- *Ra* – arithmetic mean of profile deviation from the mean,
- *Rz* – total height of profile,
- *Rq* – quadratic mean of profile deviation from the mean,
- *Rz/Ra* – calculated coefficient.

Measurements using profilograph Hommelwerke T 2000.were made in three places: 0,25, 0,50 i 0,75 of *l* dimension (length) on measuring length (4 mm) situated on the middle of samples thickness *b*. Displacement of measuring lengths were presented in Fig. 1. As a final finding average value of 3 measurements (m_1, m_2, m_3) was accepted.

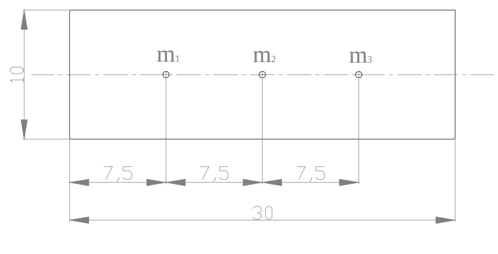


Fig. 1. Sample dimensions and measuring places on the machined samples

Presented investigations have initial character, verifying methodic possibilities, so mentioned above three elements set of roughness parameters, measured by means of mentioned metrological device one accepted as adequate.

3. Results of experimental investigations

Cutting surface roughness measurement findings are taken down in below tables. The values of roughness parameters provided in Table 1 refer to the cutting of steel samples quenched and tempered up to 43 HRC. Based on the analysis of these results it was appeared that the tested cutting parameters had an effect on the obtained roughness. It was found that roughness is also higher for greater values of parameters, e.g. *Ra* parameter increased by 0.61 micrometer, i.e. by almost 30 % (from 2.16 to 2.77 μm), where there was a change in the feed rate *f* from 64 to 96 mm/min, i.e. for an increase by 50%.

The values roughness parameter are also caused by changes of the jet pressure. At the feed rate *f* = 64 mm/min, an increase in the pressure *p* from 200 to 250 (25%) resulted in an increase in *Ra* parameter but only by ca. 12%. At different feed rates, an increase in roughness, expressed in a change of *Ra* parameter, is even lower (ca. 6%).

Table 1. Values of roughness parameters of surface cut by means of AWJM for steel sample

Feed rate, *f*, mm/min / Pressure *p*,MPa	64	80	96
Ra, μm			
200	2,16	2,68	2,77
250	2,42	2,85	2,95
Rz, μm			
200	11,20	11,80	13,17
250	13,29	14,42	15,99
Rq, μm			
200	2,74	3,26	3,37
250	3,13	3,59	3,75

Changes found in the geometrical structure of the surface being cut are described by regression equations which have the following form in the analysed case:

- for *p* = 200 MPa:
  - $Ra = -0{,}215 \cdot f^2 + 1{,}165 \cdot f + 1{,}21$
  - $Rz = 0{,}385 \cdot f^2 - 0{,}555 \cdot f + 11{,}37$
  - $Rq = -0{,}205 \cdot f^2 + 1{,}135 \cdot f + 1{,}81$
- for *p* = 250 MPa:
  - $Ra = -0{,}165 \cdot f\,2 + 0{,}925 \cdot f + 1{,}66$
  - $Rz = 0{,}220 \cdot f\,2 + 0{,}470 \cdot f + 12{,}60$
  - $Rq = -0{,}150 \cdot f\,2 + 0{,}910 \cdot f + 2{,}37$

Statistical calculations demonstrate that the above equations record very well observed changes, what is confirmed by the values of correlation coefficients approximating to 1,0.

The second structural material used in the study was syenite – mineral material (rock), using e.g. in very precise machine-tools and measurement machines (tables, bodies) but on the other hand – in civil engineering too. The results of measurements presented in Table 2 indicate that the surface roughness obtained as a result of abrasive-water jet cutting is similar for all analysed values of parameters. Maximum differences are in the range 5÷8%

Table 2. Values of roughness parameters of syenite samples surface cut by means of AWJM

Pressure, *p*, MPa \ Feed rate, *f*, mm/min	64	80	96
Ra, µm			
200	3,93	3,85	3,78
250	3,87	3,74	3,70
Rz, µm			
200	18,58	18,18	17,98
250	17,44	17,16	17,01
Rq, µm			
200	4,92	4,82	4,74
250	4,85	4,69	4,64

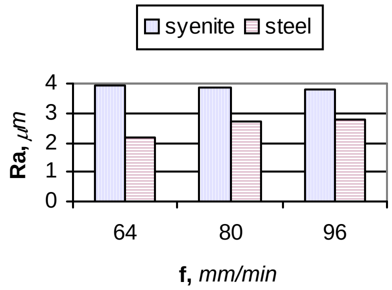
Change in feed from 64 to 96 mm/min, i.e. by 50 % results in a change of the average value of *Ra* parameter from 3.93 to 3.78 µm, i.e. its decrease but only ca. 4%. Similar situation occurs where jet pressure is changed: an increase in the value of this process parameter from 200 to 250 MPa (25%) results in *Ra* parameter value being decreased from 3.93 to 3.87 µm, i.e. only 1.5%. Similar relations occur for other analysed roughness parameters. Relations for this material were described by mathematical models. Their forms are presented below:

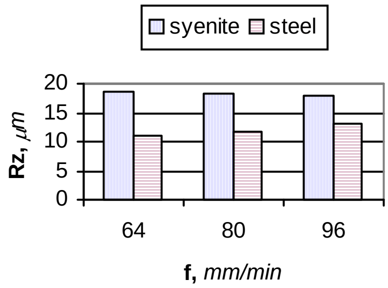
- for p = 200 MPa:
    - $Ra = 0,045 \cdot f 2 - 0,265 \cdot f + 4,09$
    - $Rz = 0,100 \cdot f 2 - 0,700 \cdot f + 19,18$
    - $Rq = 0,055 \cdot f^{2} - 0,325 \cdot f + 5,12$
- for p = 250 MPa:
    - $Ra = 0,005 \cdot f 2 - 0,095 \cdot f + 4,02$
    - $Rz = 0,065 \cdot f 2 - 0,475 \cdot f + 17,85$
    - $Rq = 0,010 \cdot f^{2} - 0,130 \cdot f + 5,04$

The analyse indicates that in analysed range of independent variables (feed rate and jet pressure) for both materials (steel and syenite) pressure has a minor influence on the obtained roughness parameter *Ra* but recorded gradient is greater for the cutting of steel. Other parameters are very similar in quality. Comparison of the results obtained for two structural materials very different from each other shows that there are essential differences, see Fig.2.

An increase of steel machining parameters (feed rate and jet pressure) resulted in increase of roughness parameters in cut surfaces, whereas in the case of mineral material a reverse tendency was observed: greater values of process parameters resulted in smaller surface roughness. Such situation may result from the water and abrasive jet containing mineral grains and so, in the case of syenite, mineral machines mineral making the hardness of the tool and the hardness of the machined object similar.

As far as the cutting of steel is concerned, the difference in hardness is greater and therefore the relations between analysed factors are similar to those in traditional machining. It is assumed that the hardness of the tool should be larger than that of the machined element by at least 30 HRC.





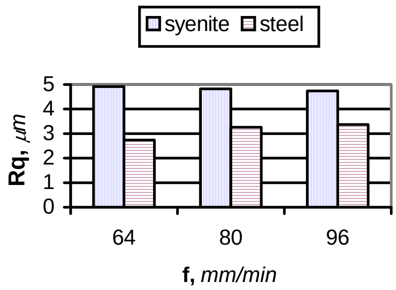
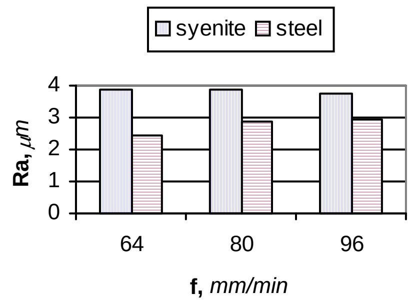
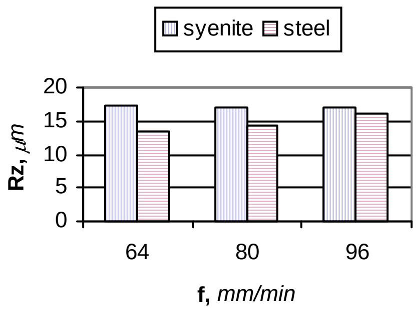


Fig. 2. Histograms presenting changes of roughness parameters: Ra, Rz and Rq of the steel and syenite samples surfaces after AWJM at the jet pressure p = 200 MPa

Comparison of histograms shown in Fig. 2 and 3 indicate that the roughness of the cut surfaces, machined with the same parameters, is much greater (even 50%) for syenite than for steel. Furthermore, it can be seen that the values of all measured parameters of cut surfaces, machined in the same parameters, are greater for mineral material than for steel.





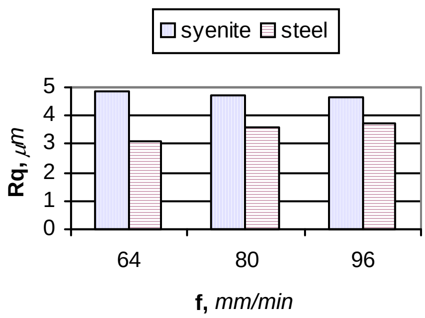


Fig. 3. Histograms presenting changes of roughness parameters: Ra, Rz and Rq of the steel and syenite samples surfaces after AWJM at the jet pressure p = 250 MPa

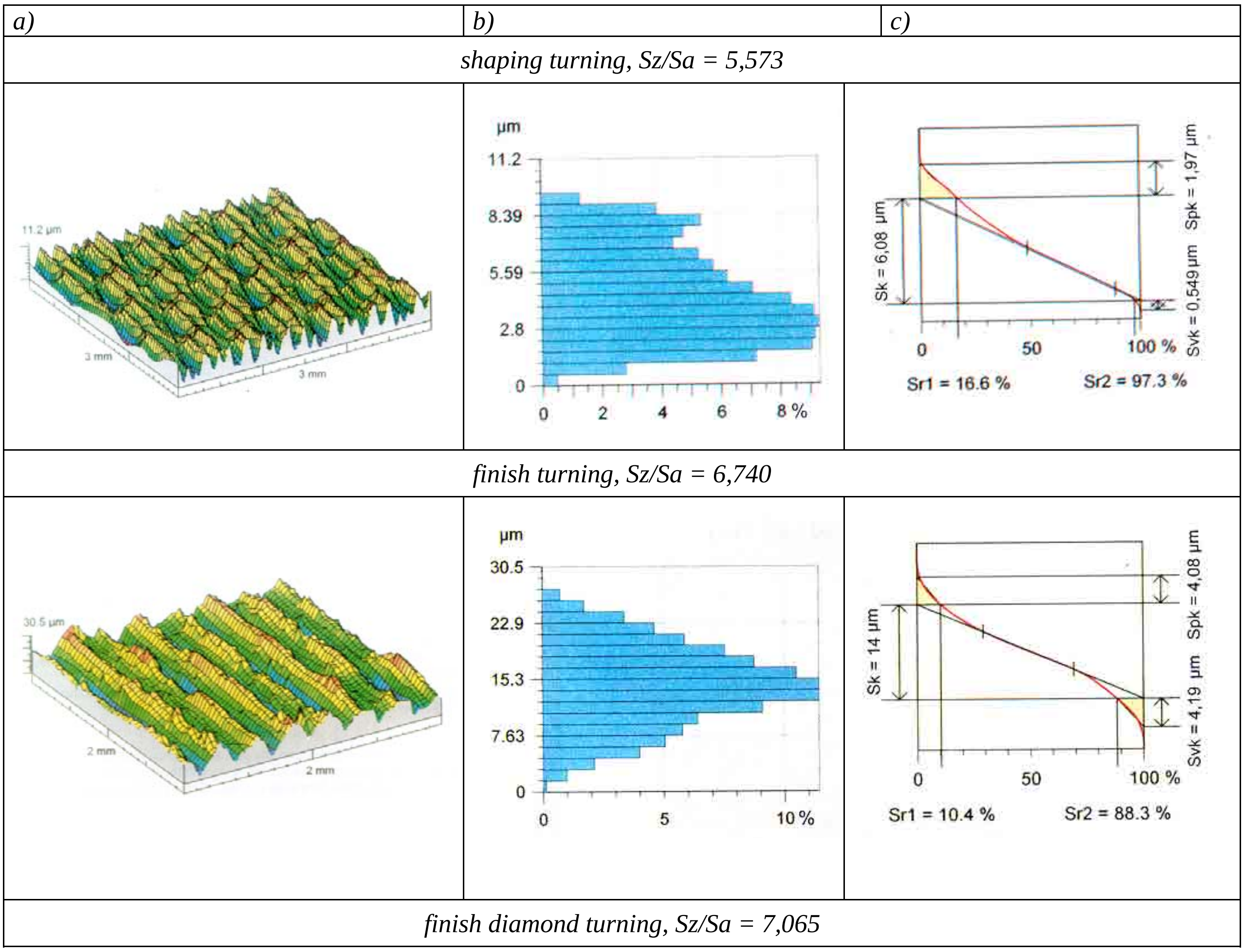
The parameters of cut surfaces roughness make this treatment to be defined as a roughing one, so it can be assumed that this method of cutting can be useful with regard to elements of which machined surfaces will be subject to further treatment. However, the AWJM method is not recommended for surfaces which are not machined after cutting.

Table 3 consists calculated quotient values of two measured roughness parameters *Rz* and *Ra*. Value of this quotient is important for various reasons, among other for tribologic features of machined surfaces what is confirmed in [5].

Table 3. Values of quotient Rz/Ra for surfaces cut with different parameters

Jet pressure MPa	Values of quotient *Rz/Ra*			
	steel		syenite	
	feed rate *f*, mm/min			
	64	96	64	96
200	5,22	4,75	4,68	4,82
250	5,53	5,42	4,49	4,61

On the ground of presented findings one can state that quotient of analysed parameters was increased together with machining accuracy increase. In Fig. 4 there were presented results of mentioned investigations. Shaping and finishing turning was compared. As the object of comparison 3D view of machined surfaces, ordinates distribution and load capacity curves were accepted.



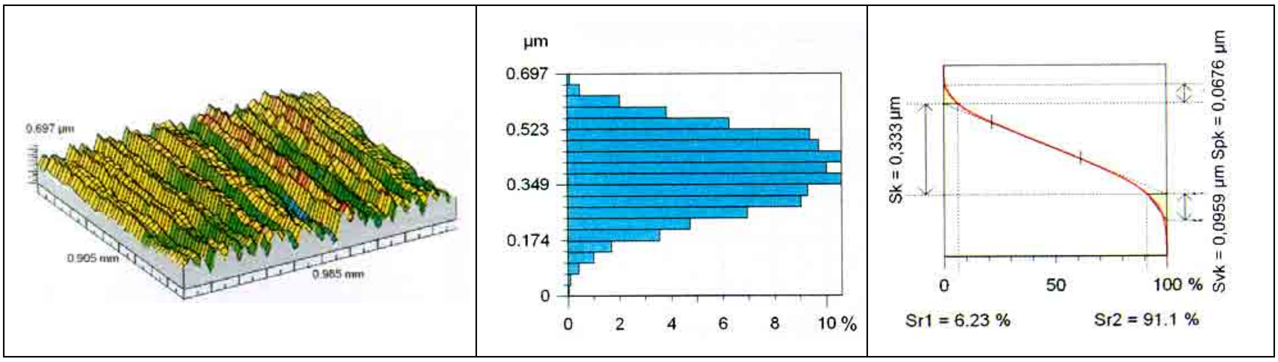


Fig 4. Comparison of turning surfaces tribology features: a) 3D surface view, b) ordinates distribution, c) load capacity curve, acc. to [5]

The views of machined surfaces are not much differentiated, besides kind of machining was differ. Visible difference were observed in ordinates distribution and load capacity curves. Allowing results of mentioned investigations, on the ground of findings contained in Table 5 one can state that for steel samples enlargement of jet pressure generates slight only (ca. 6%) increase of quotient, so load capacity of such surface will be greater too. Other relationships are for feed rate. Greater feed resulted smaller quotient value, so tribologic features will also worse.

Analysing quotient of *Rz* and *Ra* values for syenite samples inversely (than for steel) relationships were observed, namely:

- greater jet pressure – smaller quotient value – worse tribology features and
- greater feed rate – greater quotient value – better tribologic features.

4. Conclusions

On the ground of presented experiments and the analysis of the selected roughness parameters measurements results obtained from such experiments, conclusions of practical nature can be formulated. The most significant of which are as follows:

- abrasive water jet method can be used for the cutting of structural materials with various chemical compositions and structure – with satisfactory efficiency,
- roughness level of the cut surface using the AWJM method defines this method as roughing,
- influence of machining parameters of AWJM is differentiate for different machined material.

As one said above, the experiments presented in this article have initial character, so on the base of obtained results one can conclude that the established aim of research was accomplished.

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