SOME SURFACE LAYER FEATURES AFTER ABRASIVE-WATER JET CUTTING

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In presented paper results of comparative studies into the roughness (very significant tribological factor) of surfaces after cutting using the AWJM method were presented. Cutting was performed on samples made of three materials: quenched and tampered alloy steel (1.2080), plastic (polyamide PA6) and mineral material (syenite). Variable parameters in the cutting process included: jet pressure and feed. As a result of measurements involving selected roughness parameters (*Ra*, *Rz* and *Rq*). It was discovered that the majority of variable factors had a significant effect on the cut surface roughness. It was also demonstrated that the contact method measurements cannot be performed with regard to plastics because the results are characterised by a very great scatter of results values, making them unreliable.

1. Introduction. Cutting is operation very often existing in modern manufacturing processes. This process 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). Cutting is 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 yet different to cutting followed by further treatment.

Investigations presented in the 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 [1, 2], but still defined as non-conventional treatment [3, 4].

The main aim of the investigations was to verify to what extent parameters of cutting using the AWJM method affect surface layer, especially the geometrical structure of cut surfaces of elements made of material having very different features: steel, plastic and 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. Object and range of investigations. Experiments concern to cutting samples with a rectangular cross-section ($b \times h$) 30 × 10 mm, made of three different materials:

– very popular tool steel, numbered 1.2080, symbol acc. to European Standard: X210Cr12, quenched and tampered to 43 HRC;

– polyamide plastic, marked PA-6;

– syenite.

Used in investigations materials have strength feature quite differ. 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 references, e.g. [5, 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:

– R_a – arithmetic mean of profile deviation from the mean;

– R_z – total height of profile;

– R_q – quadratic mean of profile deviation from the mean.

Measurements using profilograph Hommelwerke T 2000 were made in three places: 0,25, 0,50 i 0,75 of b dimension (widthness) on measuring length (4 mm) situated on the middle of samples thickness h. As final result average value of 3 measurements was accepted.

Presented research have initial character, verifying methodic possibilities, so three elements set of roughness parameters, measured by means of mentioned 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. R_a 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 R_a parameter but only by 12 %. At different feed rates, an increase in roughness, expressed in a change of R_a parameter, is even lower (ca. 6 %).

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

Pressure p, MPa	Feed rate f, mm/min		
	64	80	96
R_a, µm			
200	2,16	2,68	2,77
250	2,42	2,85	2,95
R_z, µm			
200	11,20	11,80	13,17
250	13,29	14,42	15,99
R_q, 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 – Table 2.

Table 2 – Mathematical models obtained for steel samples for individual pressures

$p = 200$ MPa	$R_a = -0{,}215 \cdot f^2 + 1{,}165 \times f + 1{,}21;$ $R_z = 0{,}385 \cdot f^2 - 0{,}555 \times f + 11{,}37;$ $R_q = -0{,}205 \cdot f^2 + 1{,}135 \times f + 1{,}81$	$p = 250$ MPa	$R_a = -0{,}165 \cdot f^2 + 0{,}925 \times f + 1{,}66;$ $R_z = 0{,}220 \cdot f^2 + 0{,}470 \times f + 12{,}60;$ $R_q = -0{,}150 \cdot f^2 + 0{,}910 \times f + 2{,}37$

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.

Roughness parameters of the polyamide samples surfaces on which the cutting operation was performed are characterised by a very high scatter of values. This is confirmed by calculated standard deviation values, e.g. maximum standard deviation for R_a parameter was $S = 3.06$ (where the average value of this parameter is R_a = 2,87µm). Scatter of values for other roughness parameters measured was also great.

Such characteristics of changes, in particular non-repeatability of measurement results is probably caused by the roughness parameters measurement method applied. Due to the low hardness of the sample material, the hard and thin gauging point – stylus – does not slide on the tops of ridges but machines (scratches) them instead. Therefore, rules and limitations of contact method applicability in roughness measurements should be defined. Due to the inability to perform roughness measurement using other methods (non-contact), these results are excluded from further analysis.

The third structural material used in the study was syenite – mineral material (rock), using e.g. in very precise machine-tools and measurement machines (tables, bodies). The results of measurements presented in Table 3 indicate that the surface roughness obtained as a result of abrasive-water jet cutting is similar for all analysed values of parameters.

Table 3 – Results of roughness parameters measurements of surface cutting by means of AWJM for syenite samples

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

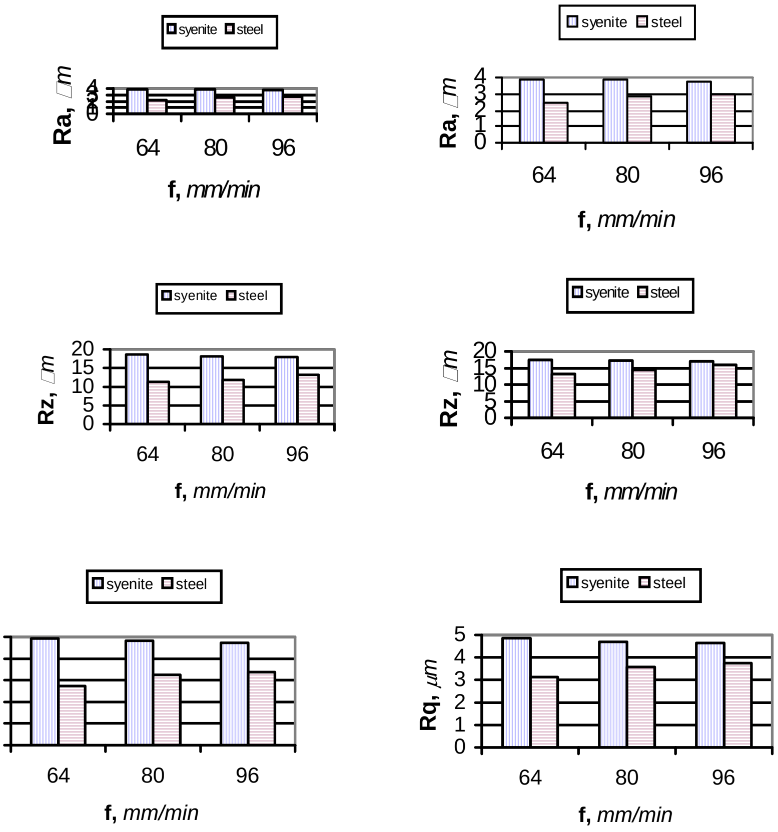
Change in feed from 64 to 96 mm/min, i.e. by 50 % results in a change of the average value of R_a parameter from 3.93 to 3.78 µm, i.e. its decrease but only ca. 4 %. Similar situation occurs where jet pressure is changed: an increase in the value of this process parameter from 200 to 250 MPa (25 %) results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

Table 4 – Mathematical models obtained for syenite samples for individual pressures

$p = 200$ MPa	$R_a = 0,045 \cdot f^2 - 0,265 \times$ $\times f + 4,09;$ $R_z = 0,100 \cdot f^2 - 0,700 \times$ $\times f + 19,18;$ $R_q = 0,055 \cdot f^2 - 0,325 \times$ $\times f + 5,12$	$p = 250$ MPa	$R_a = 0,005 \cdot f^2 - 0,095 \times$ $\times f + 4,02;$ $R_z = 0,065 \cdot f^2 - 0,475 \times$ $\times f + 17,85;$ $R_q = 0,010 \cdot f^2 - 0,130 \times$ $\times f + 5,04$

It will be easier compare the results obtained for analysed materials. The analysis indicate that in both analysed cases (steel and syenite) pressure has a minor influence on the obtained roughness parameter R_a 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 – Fig. 1.

An increase in steel treatment parameters (feed and pressure) resulted in an increase of rough-ness 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.



a *b*

Fig. 1 – Histograms showing changes in roughness parameters: R_a, R_z and R_q of the steel and syenite samples surfaces being cut recorded at the jet pressure of *a*) p = 200 MPa, *b*) p = 250 MPa

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.

Diagrams in Fig. 1 indicate that the roughness of the cut surfaces, machined with the same parameters, is much greater for syenite than for steel. Furthermore, it can be seen that the values of all measured parameters of machined surfaces where the parameters are the same are greater for mineral material than for steel.

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.

4. Summary. 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,

– the contact method cannot be used for measurements of values describing geometrical structure of cut surfaces in the case of plastics because its results do not allow comparative analyses to be performed due to the very great of values of results scatter.

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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МОДЕЛЮВАННЯ РЕЖИМУ ДИНАМІЧНОГО ЗЧЕПЛЕННЯ–ПРОКОВЗУВАННЯ ПРИ КОНТАКТНИХ МІКРОПЕРЕМІЩЕННЯХ

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Зношування при фреттинг-корозії виникає між контактними деталями при малих тангенціальних відносних переміщеннях. Зношування при фреттинг і фреттинг-корозії зазвичай відбувається на сполучених поверхнях валів з напресованими на них підшипниками кочення, на осях і ступицях коліс, на опорах поверхонь пружин, на затягнутих стиках, на поверхнях шпонок і пазів, на опорах двигуна, коробок передач. В результаті фреттинг-корозії втомна міцність поверхні зменшується в 3–6 разів. Основними кількісними показниками тертя є сила тертя і коефіцієнт тертя.

Ставиться задача визначення характеристик фрикційної взаємодії реальної поверхні контакту при гармонічному збуджені одного з тіл. Для цього розділимо переміщення точок приконтактного шару, які мають відповідну контактну жорсткість і переміщення всього тіла в цілому. Це дасть змогу адекватно оцінювати результати експерименту та математичну модель, передбачити поведінку контактних поверхонь, відповідне зношування, втрати енергії та величини тангенціальних деформацій в контакті [1, 2].

Перші дослідники, які акцентували увагу на динаміку режиму зчеплення–проковзування були B.W. Sakmann та B.G. Rightmire (1948) у своєму науковому звіті [3]. На рис. 1 представлені оригінальні осцилограми фретинг процессу та гістерезисні петлі для РДЗП при амплітуди