FOCUSING TUBE WEAR INFLUENCE ON SURFACE QUALITY AT ABRASIVE WATERJET CUTTING

ОТНОСНО ВЛИЯНИЕТО НА ТРЪБНОТО ИЗНОСВАНЕ ВЪРХУ КАЧЕСТВОТО НА ПОВЪРХНОСТТА ПРИ АБРАЗИВНО ВОДНОСТРУЙНО РЯЗАНЕ

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Abstract: *The paper deals with evaluation of the influence of focusing tube wear on surface quality created by abrasive waterjet cutting. For the purpose of qualification and quantification of the influence of the focusing tube wear influence (increase of the inner diameter) two experiments have been provided, where we simulated the influence of the increasing of the inner diameter of the focusing tube with the interaction of the further main abrasive waterjet factors such as abrasive mass flow rate, traverse speed and the pressure of the permeate on a surface profile parameter the average roughness Ra. It has been observed that focusing tube wear has a negative significant influence on surface quality at the cutting both experimental materials the stainless steel AISI 304 and aluminium.*
***KEYWORDS**: ABRASIVE WATERJET, FOCUSING TUBE, SURFACE QUALITY*

1. Introduction

Abrasive waterjet technology (AWJ) is a cold cutting process which is rapidly developing technology that is used in industry as a basic tool for various applications, including plate profile cutting, machining of a range of metallic or non metallic materials by an abrasive waterjet tool that is specific in its consistence of three phases (liquid, solid and fluid) [1], [2], [3], [4] which is formed in focusing tube. The focusing tube needs to be replaced depending on requested cutting quality requirements. But the focusing tube is one of the most wearable parts on time in the abrasive waterjet technology, which one the consequence is increasing of the inner diameter of the focusing tube. As the inner diameter of the focusing tube increases, there is a probability that it affects the quality of the AWJ tool - the density and solid phase orientation in liquid phase entering the cutting process of materials. Hence from the machining point of view it is useful to know an influence of focusing tube inner diameter on surface quality which has not been exactly explained.

2. Related Works and Problem Definition

Technological process of the cutting by means of abrasive waterjet is provided at production equipment by means of tool – abrasive waterjet, that properties characteristics are not degraded in operation time in contrast to classical cutting tool. But in case of the abrasive waterjet technology, the most wearable part of the AWJ equipment is a focusing tube (Fig. 1).

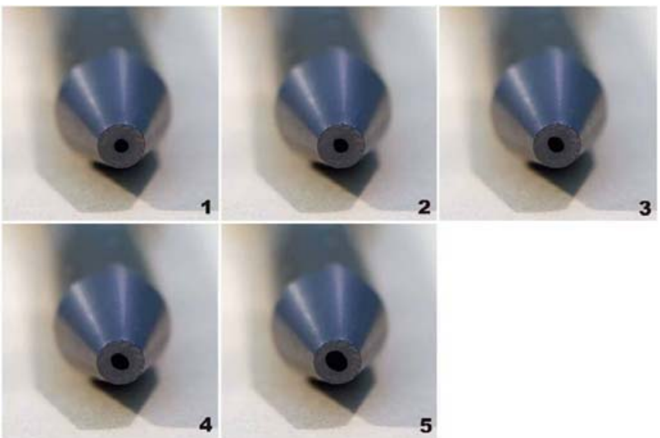

Fig. 1. Wear profiles of the focusing tube – Premium Composite Carbide (photographical record performed at company DRC., ltd., Prešov, Slovak Republic).

In focusing tube the abrasive waterjet stream is formed. Focusing tube amortization is evident after relatively long time interval, but negative effect on surface quality. On photographs (Fig. 1), obtained in cooperation with DRC, Ltd., company in Prešov there are illustrated wear profiles, increased of inner diameter of focusing tube for each wear degree. Wear of focusing tube is resulted by wear and impact of the abrasive particles in the mixing process at the focusing tube wall. According to measured deviation of the cutting accuracy there have been estimated five degrees of the focusing tube wear, where the size of the inner diameter d_f is estimated in following tolerances by means of empirical knowledge of the operator:

1. wear degree – d_f = 0,89 to 0,90 mm;
2. wear degree – d_f = 0,91 to 1,00 mm;
3. wear degree – d_f = 1,01 to 1,10 mm;
4. wear degree – d_f = 1,11 to 1,20 mm;
5. wear degree – d_f = 1,21 to 1,30 mm.

Depending on an abrasive mass flow rate m_a and an operation time t the degrees of wear are different.

3. Experiments

The evaluation of the quality of machined surface is based on the judgment of its roughness parameter *Ra* [5], [6]. Theoretical roughness depends exclusively on AWJ tool geometry and an applied process of machining whereas a real roughness appears as the result of theoretical roughness though with bigger or less occasional roughness provoked by the investigated factor – focusing tube wear with interaction of abrasive mass flow rate m_a [g.min^{-1}], traverse speed v [mm.min^{-1}] and pressure p [MPa]. In order to investigate the influence of the AWJ factors on average roughness *Ra* cutting quality, full factorial design for four independent variables has been designed, where is statistically simulated the influence of the focusing tube wear with interaction of abrasive mass flow rate m_a [g.min^{-1}], traverse speed v [mm.min^{-1}] and pressure p [MPa]. Full factorial analysis was used to obtain the combination of values that can optimize the response, which allows one to design a minimal number of experimental runs. Four factors submitted for the analysis in the factorial design of each constituent levels [–1; +1]. The experiments were carried out based on the analysis using Statistica 7.0 and Matlab to estimate the responses of the surface profile parameter average roughness *Ra*. A two dimensional abrasive waterjet machine Wating, was used in this work with following specification: work table x-axis 2000 mm, y-axis 3000 mm. The high-pressure intensifier pump was used the Ingersoll-Rand Streamline model with maximum pressure 380 MPa. As a cutting an Autoline cutting head from Ingersoll-Rand head has been used. As a target material has been used aluminium alloy and austenitic stainless steel AISI 304. The abrasive Barton

Garnet MESH 80 was delivered to the cutting head by means of tubing with inner diameter of 8 mm with feeding precision ± 5%. Standoff of the focusing tube from top of target material was 3 mm. The properties of each sample are: length 35 mm, width 8 mm, and height 10 mm. Each cut has been replicated three times; yielding total of 96 cuts. A surftest Mitutoyo 301 has been used to calculate the average roughness *Ra* with 0.01 µm precision of measurement. The measurement procedure consisted of measure variable dependent *Ra* in 1, 5 and 9 mm with replicates of 6-times yielding total of 1728 measurements.

4. Statistical evaluation, results and discussion

The quantitative description of the conditions effects on average roughness was performed. Response surface methodology is an empirical modelling technique used to evaluate the relationship between a set of controllable experimental factors and observed results. The results were analyzed using the analysis of variance as appropriate to the experimental design used. The normality of experimental measured data has been tested according Shapiro-Wilkson test criteria for its good power properties as compared to a wide range of alternative tests. Regression coefficients have been calculated by means of Statistica 7. The regression coefficients and equations obtained after analysis of variance gives the level of significance of variable parameters tested according to Student's t-test. Obtained regression coefficients that show no statistical significance has been reject from the further evaluation. These results can be further interpreted in the Pareto Charts, which graphically displays the magnitudes of the effects from the results obtained. Fig. 2, 3 graphically displays the influence magnitudes of the evaluated factors main effect and their interactions on surface profile parameter *Ra* [µm] measured on three depth traces a) h = 1 mm, b) h = 5 mm, c) h = 9 mm of the stainless steel AISI 304, b = 10 mm (Fig. 2) and aluminium (Fig. 3), which are sorted from largest to smallest, from obtained results.

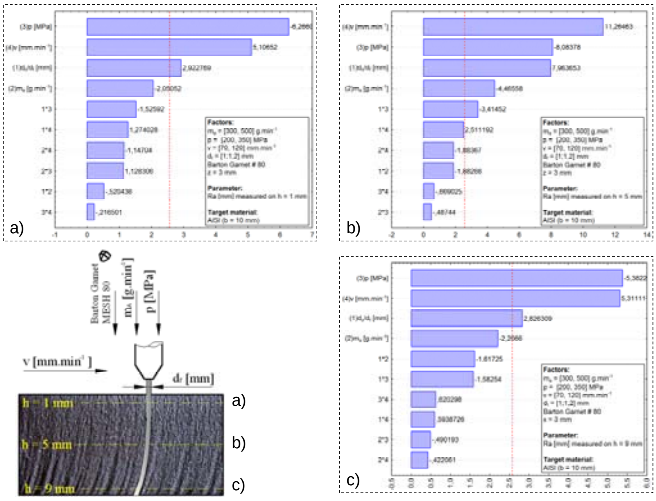

Fig. 2. Influence and significance of the factors main effect and their interactions on surface profile parameter Ra [µm] measured on three depth traces a) h = 1 mm, b) h = 5 mm, c) h = 9 mm of the stainless steel AISI 304, b = 10 mm, interpreted by means of Pareto Charts.

The most important factors affecting the parameter average roughness *Ra*. For a consideration of these Pareto Charts, can be easily identified causalities, that most deteriorate the quality process and to separate them from less significant. From Pareto analysis results that influence of focusing tube wear on surface profile parameter *Ra* is significant on all depth traces. On depth trace (Fig. 3) h = 1 mm is factor df the most significant at the cutting of the aluminium. The trace line in shallow depth has been chosen in order to verify the surface profile parameter in shallow depths, where are coded information about first contact of abrasive waterjet stream with target material as well as whole technology. On the depth of 5 mm the parameter average roughness is affected by interaction of the two factors; focusing tube diameter and traverse speed (Fig. 3b). The second most significant factor which significantly affects the measured parameter *Ra* is main effect of the factor - diameter of the focusing tube. From the results follows that the most important factors that affects the surface quality parameters at the cutting of the soft materials are mainly the focusing tube diameter at the shallow depths and the traverse speed, abrasive mass flow rate, in depth of 9 mm that is connected with reduction of the kinetic energy of the stream, which is absorbed by eroded material. On depth trace h = 5 mm (Fig. 3b) it is evident that at the cutting of the aluminium there is significant the interaction of the focusing tube d_f and traverse speed v, which confirms, that diameter of the abrasive waterjet stream is deformed with an increase of the traverse speed. On depth of 9 mm is effect of the focusing tube significant, after traverse speed v. In that case we can assume, that at the cutting of the soft materials as aluminium, the surface profile parameter *Ra* is mainly affected by focusing tube diameter, because the less diameter of the focusing tube, or the less wear of the focusing tube is, the concentration of the abrasive particles on peripheral part of the stream will be higher, which will mean relatively smooth cutting of the material.

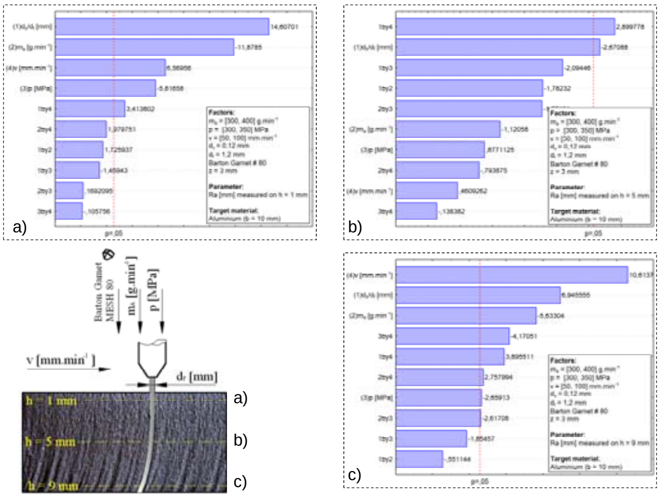

Fig. 3. Influence and significance of the factors main effect and their interactions on surface profile parameter Ra [µm] measured on three depth traces a) h = 1 mm, b) h = 5 mm, c) h = 9 mm of the aluminium b = 10 mm, interpreted by means of Pareto Charts.

Opposite situation has been observed at the experimental cutting of the austenitic stainless steel AISI 304. In that case the dominant factor is pressure that represents one of the most important factors, which is necessary for the destruction of the hard materials. The second significant factor, according to Student criterion is the traverse speed v (Fig. 2). The third significant factor is the focusing tube diameter d_f. It means that for optimisation purposes and for optimal set selection it is necessary to take into account the focusing tube wears that have a negative effect on cutting kerf width and surface roughness. The surface quality is dependent on a focusing tube wear that is very important for design of the algorithm for on-line control of AWJ technology.

5. Conclusion

It raises the manufacturing costs on production by production process extension, which decreases competitiveness. In the paper it was concerned to study the focusing tube wear on surface quality produced by abrasive waterjet by means of experiments design. According to full factorial analysis for the further optimalization and the process factors selection it is necessary to take in to account the wear of focusing tube, which has the negative influence on surface profile parameter *Ra* as a factor at creating of the algorithm for on-line control of abrasive waterjet cutting technology. From the evaluation of statistical and physical-analytical rules between the input and the output quantities, it is possible to proceed the mathematical generalization of these rules and the deducing of statistical and physical equations for predictive and design calculations of particular cuts.

Acknowledgment
The authors would like to acknowledge the support of Scientific Grant Agency of the Ministry of Education of Slovak Republic, Commission of mechanical engineering, metallurgy and material engineering, for their contribution to project VEGA 1/4157/07 and to projects MŠMT č.MSM6198910016, GA ČR 101/09/0650.

6. References

[1] Hloch, S., Gombár, M., Fabian, S., Straka, L., (2006) Factor analysis of abrasive waterjet process factors influencing the cast aluminum surface roughness, In: Manufacturing Science and Technology. Malaysia, pp. 145–149.

[2] Hascalik, A., Caydas, U., Gurun, H. Effect of traverse speed on abrasive waterjet machining of Ti–6Al–4V alloy. In. Materials & Design, Volume 28, Issue 6, 2007, pp. 1953-1957.

[3] Kulekci, K., M. Processes and apparatus developments in industrial waterjet applications. International Journal of Machine Tools & Manufacture 42 (2002) 1297–1306.

[4] Lemma, E. et al. / International Journal of Machine Tools & Manufacture 42 (2002) 781–789 787.

[5] Valíček, J., Hloch, S. (2006) Surface topography optical identification generated by abrasive waterjet. In: Fine Mechanics and Optics. vol. 51, no. 11-12, pp. 320-322.

[6] Valíček, J. et al. Method of the determination of superposition relation of changes in surface geometry to mechanical parameters of material due to corrosion. In: Acta Mechanica Slovaca. roč. 9, č. 3-a 2005 interantikor 2005 (2005), s. 171-176. ISSN 1335-2393.