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STAINLESS STEEL SURFACE TOPOGRAHY STUDY IN INITIAL ZONE CREATED BY ABRASIVE WATER JET

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Abstract: *The paper deals with detailed study topography of surfaces created by abrasive water jet in upper area of work piece known as initial zone that is neglected by many authors and researchers. Experimentally produced surfaces under various conditions defined by design of experiments have been analyzed by non-contact commercial profilometer MicroProf FRT. Irregularities of surfaces from stainless steel AISI 304 have been quantified by surface profile parameters Ra, Rq and Rz which have been obtained by Gwyddion software from 25 depth traces. The results have been statistically evaluated. It is a preliminary detailed study of neglected upper zones. Results obtained in the experimental part of the work, will serve as an important basis for further experimental research.*

Key words: *abrasive waterjet, initial zone, surface topography.*

1. INTRODUCTION

The quality of an abrasive water jet-made cut is of the utmost importance in cutting of materials. Any improvement in the area will eliminate post-machining operations. Currently the mechanism of the abrasive water jet cutting is not still understood as evidenced in new research reports of [1, 2]. The great lacks in that field are irregularities of the surface created by abrasive waterjet in neglected initial zone. The aim of our work is to carry out a comprehensive view of the surface topography in the initial zone created by AWJ, classification of the shortcomings of classical (contact) the method of evaluation of the quality of the surface in the zone where the first contact with the material, confirmation of the existence of initial zone and their further study. The present work has been created in collaboration with company DRC Prešov, Ltd., where experimental samples were made. Measurements of surface profile parameters *Ra*, *Rq* and *Rz* has been made at Technical University of Brno.

2. RELATED AND PREVIOUS WORKS

Topography of the surface created by AWJ of relatively thick material consists of a smooth upper zone and a striated, wavy lower zone. Authors [4, 10, 13, and 14] divide the surface, which is generated by AWJ on the mechanism of removal in the cutting mechanism and deformation mechanism. According research report published by [3] is a typical surface topography created by AWJ characteristic differences in horizontal bands. Authors [3] introduced the topography divided into three areas: the initial zone, smooth and rough zone. The shape of the cut walls depends on the front spreading of WJ and AWJ from the upper to the lower side (Fig. 2). This is an image of the changes in the mechanism of disintegration. All the authors were concerned about the physical-mechanical aspects of the interaction of disintegration energy accumulated by the abrasive water jet with the mechanical structure of the material. They divide these cutting walls into an upside qualitative smooth cut and the part of the cut deformation beginning from the critical depth. Unevenness of the upper part of the cut is considered as microscopic, mostly unevenness at the roughness level. Unevenness in the lower part of the cut is already macroscopic with the presence of grooves and slots on the surface, mostly at the waviness level (Fig. 1). According to preliminary our study by using the contact profilometer the initiation zone with a rather great roughness could not be completely detected and localized.

On the contrary, results gained by an optical profilometer MicroProf (FRT), reported in study by [12], show that more detailed information on the initiation zone can be provided. From the theoretical point of view, this entry region is of importance to the subsequent clarification of a mechanism of material removal and the explanation of AWJ-material interaction in this initiation zone.

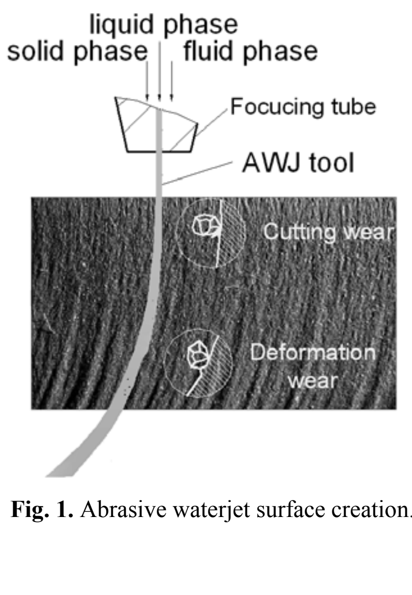

Fig. 1. Abrasive waterjet surface creation.

From the made analysis and from the obtained data on surface topography, a mechanism of formation of the surface topography, which is, as a matter of fact, a memory of machining technology and also a witness to properties of the material machined, may be deduced. For the reason of mechanical flexibility, and thus the ability of AWJ tool to accommodate itself to material properties, this tool is very suitable for theoretical analyses. It is possible to say that in terms of newly developed science disciplines of technological inheritance, a profounder analysis of the process of surface layer origin can be carried out. Author [4] divide generated surfaces from the point of view of the removal mechanism into those with the removal mechanism of cutting character and those with the removal mechanism of deformation character. According to the literature [4], the topography formed is divided into the initiation zone (which is, however, neglected by the majority of authors), the smooth zone and the rough zone (Fig. 2). In our opinion, in the framework of objectivity of the explanation of mechanism of origin of newly generated surface topography, the initiation zone cannot be ignored, because it evidences the first contact with a disintegration tool, which is here a high-energy jet of the mixture of water, air and abrasive.

Whenever two machined surfaces come in contact with AWJ tool another the quality of the mating parts plays an important role in the performance and wear of the machined parts. Most scientific papers concerning to the evaluation of microgeometrical features of abrasive waterjet cutting are available [5, 6 9.13, 14, and 15]. The objective is to determine the final shape of the surface quality, which is a function of the geometric characteristics of the tool. The roughness of the machined surface is seen through micro-geometrical irregularities of the surface. The result of this technological process depends on a large number of process factors such traverse rate v [mm.min^{-1}], abrasive mass flow rate m_a [g.min^{-1}], pressure p [MPa], focusing tube diameter d_f [mm], focusing tube length l_f [mm], stand-off distance z [mm], orifice diameter d_0 [mm], abrasive material grain size [MESH], abrasive material type, angle of impact φ [°]. Most of the papers for the evaluation of the technological process used the surface profile parameter the average roughness *Ra*. From the previous experiments and from available literature [5, 6, and 7] the average roughness parameter is not enough for adequate evaluation of any process because average roughness is sensible on extreme values as is shown on Fig. 3

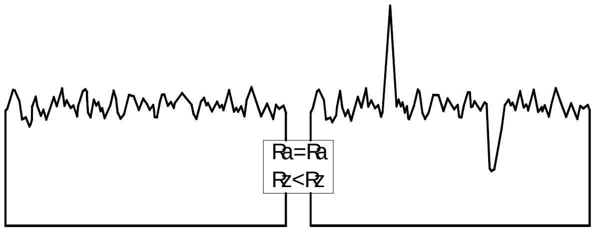

Fig. 3. An illustrative example of two equal surfaces in terms of parameter roughness profile *Ra*, but different in terms of the surface profile roughness parameter *Rz*.

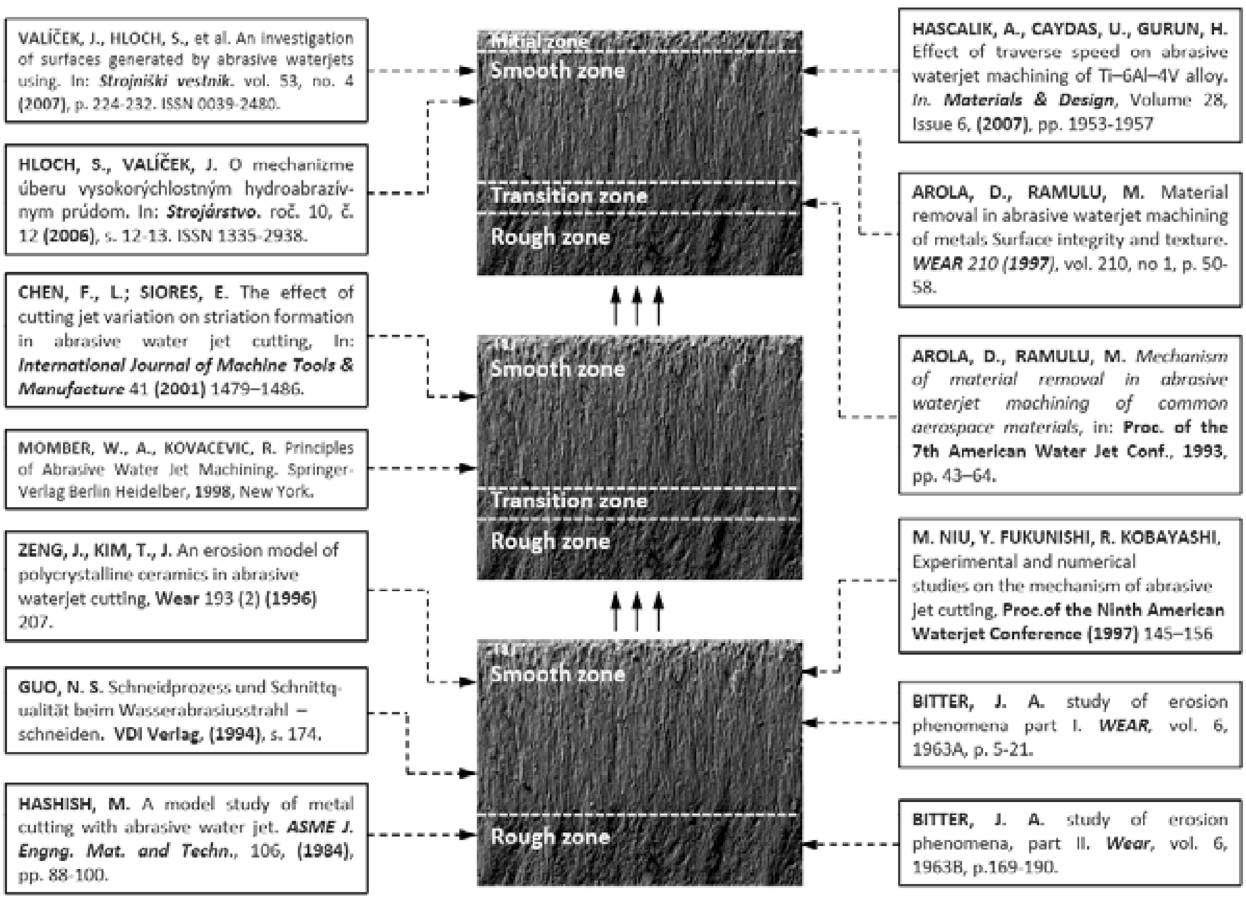

Fig. 2. Development of scientist opinions on topography divisions of surfaces created by abrasive waterjet.

3. EXPERIMENTAL SETUP

Roughness profile parameters *Ra*, *Rq* and *Rz* determinated by means of optical profilometer MicroProf FRT from manufacturer Fries Research & Technology GmbH, Germany, on a workplace of Physical engineering institute FSI VUT in Brno. By three-dimensional contactless and non-destructive measurement was obtained matrix value of altitude unevenness of surface, generated by composition of AWJ technology factors from the whole area of the surface. In the area of AWJ entry, for the purpose of identification and analysis of factors influence on topography of surface in initial zone, was the value of equidistant distances of particular depth traces from the surface 0.1 mm from to 9.5 mm. In all measurements were realized in 25 depth traces (Fig. 4). Proper measurements were realized in the central zone of the sample excluding marginal areas of the sample to reach the most accurate measurements. Each measurement was repeated 8 times to reach statistically the most accurate result.

4. RESULTS AND DISCUSSION

The following pictures (Figs. 5 and 6) are given courses of impact factors on the profile of roughness parameters *Ra*, *Rq* and *Rz* detected in 25 lines of depth to a depth of 2.5 mm, with a focus on the study of inequalities in the initiating zone is seen a sharp decline, but also an increase of *Ra*, *Rq*, R_Z, which may be due to inaccurate measurement. On the basis of repeated measurements have been generated data that were statistical processed and interpreted. As outlined in previous chapters, information on the nature of technology is stored in the uppermost layer, in the initial zone where abrasive waterjet hit the surface of the material. Characteristic surfaces in initial zone are to be found in the very technology that formed the mechanical effect abrasive waterjet disintegration tool. On produced samples by abrasive water jet it is possible to clearly distinguish the entrance area, the surface cut and exit the area (bottom part of the surface). Created surfaces and associated inequalities show the specific geometry, as they are produced by different technological conditions. Technological conditions have an impact on the physico-mechanical interactions of abrasive water jet cutting of the material, the total morphological pattern of the surface and its topography. Topography of surfaces is optically different reflected in the results of realized measurements. The overall structure of topographic surface, which is the image of technological characteristics is at the bottom portion morphologically shaped by wave with higher amplitude, namely by wavelength and lower frequency. Mechanisms for removal in the initial zone can be characterized as a volume, the surface portion of the plane and exit the area as a permanent deformation. In previous works, and states that, according to the size of the shape of the heels at the outlet stream of the cut can be re-assessed the accuracy of technological options in relation to the physico-mechanical parameters of material. This problem also analyzed the work [7, 13, 14, and 15]. In the depth is increasing the rate of pressure component, which has deformation character on material being cut.

In abrasive water jet stream, volume and weight ratio of removed material with zero kinetic energy increases.

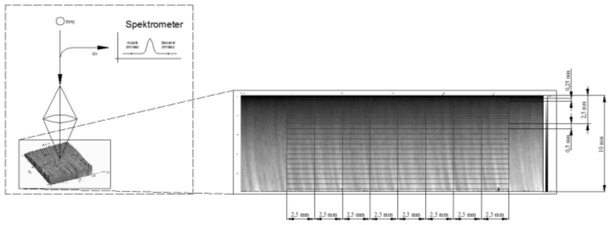

Fig. 4. Depth traces in which have been detected quantitative surface profile roughness parameters *Ra*, *Rq* and *Rz*.

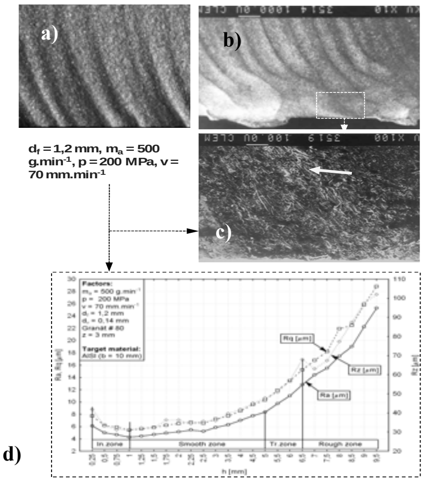

Fig. 5. a) surface produced from AISI 304 under defined conditions d_f = 1,2 mm, p = 200 MPa, m_a = 500 g.min^{-1} and v = 70 mm.min^{-1}, b) SEM photograph of surface 10x, c) surface detail with visible grooving and plastic deformation, d) topographic function including of initial zone.

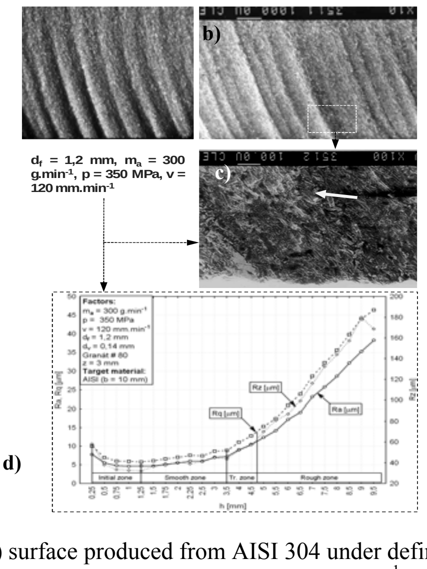

Fig. 6. a) surface produced from AISI 304 under defined conditions d_f = 1,2 mm, p = 350 MPa, m_a = 300 g.min^{-1} and v = 120 mm.min^{-1}, b) SEM photograph of surface 10x, c) surface detail with visible grooving and plastic deformation, d) topographic function including of initial zone.

This phenomenon has influence on the beginning of the deeper deformation creation. The deformation has the form of striations and deeper grooves that topographically characterize the transition stage till the end of the cut area that is deformation zone with intense increasing of pressure and deformation component occurring by plastic creeping. Striation formation mechanism is given by movement trajectories of abrasive particles and their mechanism of action on surface of the forehead cut. On Figure are shown formed surfaced by experimentally defined factors combination. From comparison shows that striation reduction is caused by high values of abrasive mass flow rate ma, with low rate of speed of cutting head *v* mm.min^{-1}. The Figs. 5 b,c and 6 b,c shows a series of SEM photos with traces of abrasive particle removal mechanism in the forefront abrasive waterjet stream. Fig. 5 b,c shows the view of the bottom area of the sample, which was created by defined structure factors. For Fig. 5,c we can clearly observe the grooves and Fig. 5,c caused by traces of abrasive particles. Orientation and length of these cut is irregular. For Fig. 6,b there is a photographic record of the bottom sample, which was produced with the higher value of the abrasive mass flow. For Fig. 6,c it is visible a plastic deformation caused by exposure to a lower pressure shallow striations, which is due to increased density of abrasive particles in the abrasive waterjet stream. For Fig. 6,c it is clearly seen traces caused by abrasive grains on top of the waves heels due to increased exposure of abrasive waterjet flow due to jet lag. Trails are irregular due to the effects of hydrodynamic flow, which lost its kinetic energy due to the lower pressure *p*. As seen from above mentioned, in terms technological herritage we can access the mechanism of the surface which "inherited" properties by means AWJ factors.

According to the author, however, this fact cannot be generalized to the whole surface. With increasing depth, on removal mechanism participates own material, which affects hydrodynamics of AWJ tool.

5. CONCLUSIONS

In technical practice, in order to automate the machining process using abrasive water jet tool, it is necessary to ensure the resulting surface quality evaluation. Due to the fact that AWJ cutting material, it is important to ensure the required quality characteristics of a constructed area of knowledge is a condition during the functional dependencies between the quality parameters Ra, Rq and Rz, and factors of production system technology AWJ.

The main thrust of paper therefore was to bring a deeper knowledge of the interaction with AWJ cutting of material on the basis of the identification and analysis of the impact of factors in relation to surface topography created by AWJ cutting. The present work points to the absence of a deeper analysis of the topography of initiating zone. For that reason, given a systematic overview of the technology cutting AWJ, which was right in terms of technology heritage necessary to detailed analyzed.

The knowledge gained will help more effective and easier to fix the quality of the forthcoming technological practice. Moreover, the results obtained in the empirical part of the work, will serve as an important basis for further experimental research.

In further study will be detailed study of surface topography in the initiation zone, which in terms of technological heredity has the highest explanatory ability of characteristics of technology using factor analysis.

REFERENCES

[1] Orbanic, H., Junkar, M. (2008), *Analysis of striation formation mechanism in abrasive water jet cutting Wear*, Vol. 265, Issues 5–6, pp. 821–830.

[2] Shanmugam, D., K., Masood, S., H. (2009), *An investigation on kerf characteristics in abrasive waterjet cutting of layered composites*, Journal of Materials Processing Technology, Vol. 209, Issue 8, pp. 3887–3893.

[3] Arola, D. and Ramulu, M. (1997). *Material removal in abrasive waterjet machining of metals surface integrity and texture*, Wear, (210), pp. 50–8.

[4] Bitter, J. (1963). *A study of erosion phenomena part I*, Wear, Vol. 6, 1963A, pp. 5–21.

[5] Hloch, S. and Gombár, M. (2006). *Roughness of stainless steel surface in the process of cutting with abrasive waterjet*, MM Spectrum, pp. 48–50.

[6] Hloch, S. and Valíček, J. (2006). *Abrasive waterjet cutting mechanism*, Strojarstvo, Vol. 10, No. 12, pp. 12–13.

[7] Hloch, S. et al. (2008). *Experimental study of surface topography created by abrasive waterjet cutting*, Strojarstvo, Vol. 49, No. 4, pp. 303–309, ISSN 0562–1887.

[8] Jurisevic, B., Coray, P.S., Heiniger, K.C., Junkar, M. (2003). *Tool formation process in abrasive water jet machining*, Proceedings of the 6th International Conference on Management of Innovative Technologies MIT'2003 – Post-Conference Edition, Ljubljana, University of Ljubljana, pp.73–85.

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

[10] Lemma E., Chen L., Siores E., Wang J. (2002). *Optimising the AWJ cutting process of ductile materials using nozzle oscillation technique*, International Journal of Machine Tools & Manufacture, Vol. 42, pp. 781–789.

[11] Martinec, P., Foldyna, J., Sitek, L., Ščučka, J., Vašek, J. (2002). *Abrasives for AWJ cutting*, Academy of Sciences, Czech Republic. pp. 80.

[12] Páleníková, K. and Ohlídal, M. (2005). *Potentialities of optical profilometer MicroProf FRT for surface quality measurement*, 14th Slovak-Czech Polish Conference on Wave and Quantum Aspects of Contemporary Optics, pp. 59451–59456.

[13] Valíček, J. et al. (2007). *Experimental analysis of irregularities of metallic surfaces generated by abrasive waterjet*, International Journal of Machine Tools and Manufacture, Vol. 47, No. 11, pp. 1786–1790.

[14] Valíček, J., Hloch, S. (2006). *Surface topography optical identification generated by abrasive waterjet*, Fine Mechanics and Optics, Vol. 51, No. 11–12, pp. 320–322.

[15] Valíček, J., Hloch, S., Radvanská, A. (2007). *Quality control of surface created by means of abrasive waterjet cutting technology*, Emerging Mechanical Technology – Macro to Nano, Proc. of the Intl. Conf., 16–18 February 2007, BITS, Pilani, India. Research Publishing Services, pp. 227–231.

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