ABRASIVE TYPE INFLUENCE ON SURFACE ROUGHNESS AT ABRASIVE WATERJET CUTTING

АБРАЗИВНОГО ТИПА ВЛИЯНИЯ НА ШЕРОХОВАТОСТЬ ПОВЕРХНОСТИ НА АБРАЗИВНЫХ ГИДРОАБРАЗИВНАЯ РЕЗКА

Sergej Hloch, Jana Mullerova, Jan Valíček
Faculty of Manufacturing Technologies of Technical University of Košice with a seat in Prešov

Abstract: *The paper deals with experimental investigation of the influence of Barton Garnet and Olivine abrasives with interaction of selected abrasive waterjet factors; standoff, traverse rate and abrasive mass flow rate on surface profile parameter average roughness by means of full factorial analysis. It has been found that type of abrasives has influence on surface profile parameter Ra.*
***KEYWORDS**: ABRASIVE WATERJET, OLIVINE, GARNET, ROUGHNESS*

1. Introduction

The manufacture of precision parts emphasizes final finish machining operations which may account for as much as 15 % of the total manufacturing costs. The abrasive waterjet technology process optimization has been accelerated because of the need for improvements in surface quality. Moreover, the process features change drastically with machining factors entering the abrasive waterjet cutting process. The shape of the cut surface depends on the front of AWJ from the upper to the lower side (Fig.1). This is an imagination of the changes in the mechanism of AWJ cutting. 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. In spite of great research effort and good knowledge in the field of progressive technologies there are numbers of unexplained facts. One of them is influence of process factors on workpiece surface quality. The work presented in this study investigates a micro-geometrical aspect of the cutting quality of the average roughness and peak-to-walley roughness. The roughness of the machined surface is seen through micro-geometrical irregularities of the surface. The result of this hydro-mechanical cutting process depends on a large number of process factors such as water pressure, orifice diameter, standoff distance, abrasive and material feed rate etc. The shape of the cutting jet stream is also very important. The evaluation of the quality of machined surface is based on the judgment of its roughness.

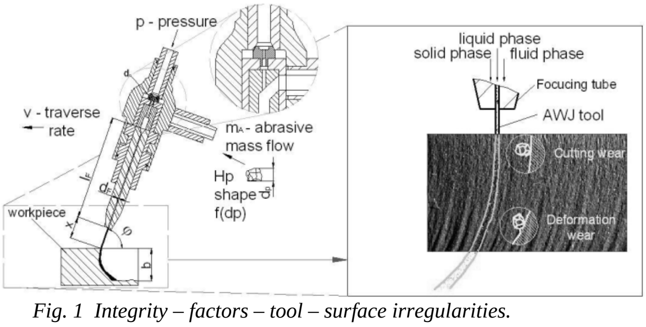

Fig. 1 Integrity – factors – tool – surface irregularities.

Theoretical roughness depends exclusively on AWJ tool geometry and applied process of machining whereas a real roughness appears as the result of theoretical roughness though with bigger or lesser occasional roughness provoked by the many factors (Fig.1).

One of the factors that influence the surface irregularities is the type of the abrasive.

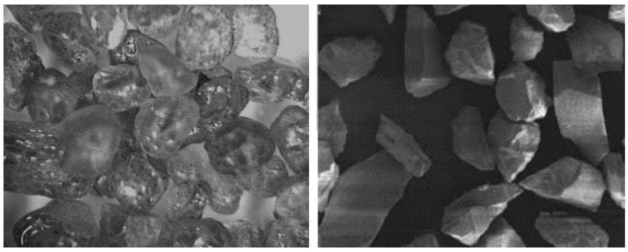

Fig. 2. Abrasives a) olivine, b) Barton Garnet

2. Experimental study

The examination of a mathematical function between the input - material, technology and the output – geometrical surface parameters is the base for their mutual influencing in the control system. The machining done by AWJ is a process difficult in terms of technology. The project preparation, optimisation and the overall result of AWJ machining are influenced by a number of factors. A 2^4 full factorial analysis has been used with 3 replicates at the center point, leading the total number of 16 experiments. Evaluated factors were standoff z [mm], traverse rate v [$mm.min^{-1}$], abrasive mass flow rate m_a [$g.min^{-1}$] and different abrasive material olivine and Barton Garnet has been used. Considering that the two levels of the x_1, x_2, x_3, x_4, and variables are -1 and 1, the designed matrix is 16-obsevations for dependent variable Ra. 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 aluminum alloy. A digital surftest Mitutoyo 301 has been used to calculate the average roughness with 0.01 μm precision of measurement (Vasilko & Vasilková, 2000).

3. Results and discussion

The quantitative description of the conditions effects on average roughness was performed. Response surface methodology is an empirical modeling 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. The regression coefficients obtained after ANOVA gives the level of significance of variable parameters tested according Student's t-test. The significance of independent variables is interpreted in the chart that shows the factors significance in percentual expression of regression coefficients. From the statistical factor evaluation of the experiment results that surface profile parameter average roughness level is dominantly influenced by tested abrasives, abrasive mass flow rate, traverse speed, the interaction between abrasive mass flow rate and the traverse rate and the standoff at the h = 1mm (Fig. 3, 4, 5).

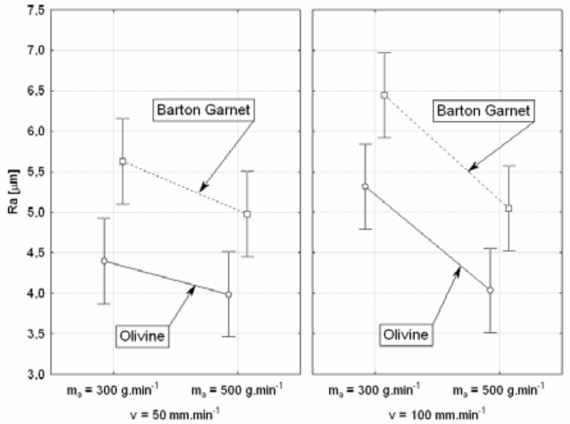

Fig. 3. Plots of marginal means for independent variables: abrasive mass flow rate ma; traverse rate v; and kind of abrasive (Aluminium h = 12 mm, Ra measured in 1mm).

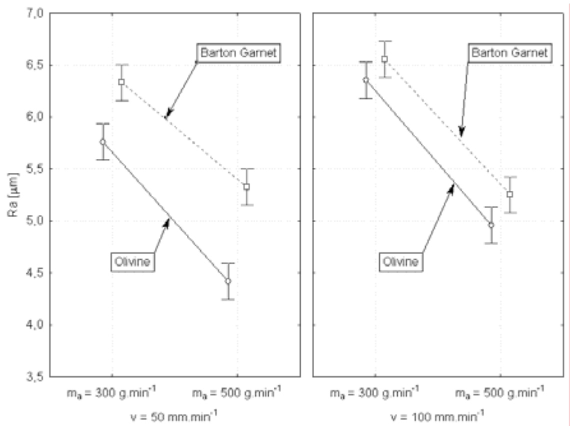

Fig. 4. Plots of marginal means for independent variables: abrasive mass flow rate ma; traverse rate v; and kind of abrasive (Aluminium h = 12 mm, Ra measured in 5mm).

Close specification of the factor combination influence are shown on following plots of marginal means for independent variables. At the traverse rate of 100 mm.min^{-1} (Fig. 3) that confirms the significance of the factors interaction v and m_a. For comparison of the same situation at h = 11 mm the hardness of the evaluated abrasives the hardness as a factor is not significant to average roughness of the aluminium (Fig. 3), (Fig. 4). The significance of the abrasive mass flow is high as the traverse speed increase and the h = 9 mm. As for the used abrasives (Fig. 4), (Fig. 4,5,6), (Olivine and Barton Garnet) the development of the numerical values of the average roughness *Ra* are the same. In that case the use of the olivine as an abrasive material at the AWJ cutting of the aluminium it is suitable to use for the cutting of the thin material. The last evaluated factors are standoff. AWJ as a floppy tool loose the cutting effectiveness a function of standoff distance.

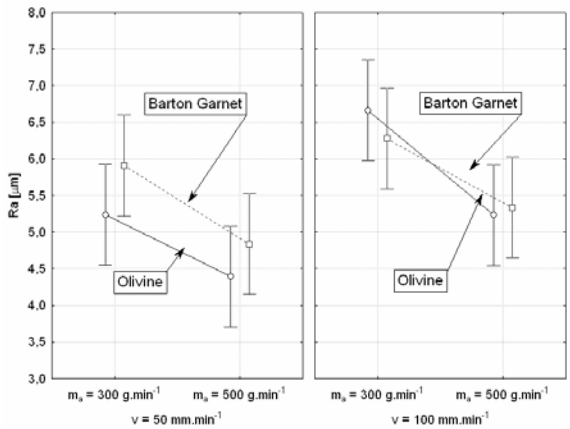

Fig. 5 Plots of marginal means for independent variables: abrasive mass flow rate ma; traverse rate v; and kind of abrasive (Aluminium h = 12 mm, Ra measured in 11mm).

4. Conclusions

From statistical physical and analytical regularity evaluation of the relationship between input and output data, it is possible to proceed to the mathematical generalization of these regularities and derive an equation for prediction and project calculation of the concrete cuts. By that calculation it could be theoretical based technology factors selection that will be optimal for the given machined material on required quality, the performance parameters and the total machining economy. This analysis has pointed out that variable independent factors influence the morphology of the cutting surface in terms micro cutting quality. It has been found that influences of selected factors are variable related to different depth. The analysis using full factorial design reveals that higher values of average roughness are caused with increasing of traverse rate. Material thickness and traverse rate and their interaction as shown previously have most significant effect to average roughness. The most important factors influencing the cutting quality of aluminium are traverse rate and abrasive mass flow rate. From performance analyses results, that smooth cut allows achievement of maximum cutting depth in given target machined material. The results will be systematically updated and statistically and analytically evaluated in order to be fully usable for the prediction of the geometrical surface state and for the project of optimisation of the main AWJ process factors, which covers all kinds of materials used most frequently in technical professions.

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 1/4157/07.

5. References

2. Gombár, M. (2006) Statistical model of surface roughness. *Electrotechnics in practise*. vol. 16, no. 11-12, pp. 26-28.
3. Matija, R., Vojtko, I. (2006) Tribological aspects of machining. *Technological engineering.* vol. 3, n. 1, pp. 44–45. ISSN 1336-5967.
4. Panda, A., Pandová, I. (2000) Statistical process control (SPC) principles of statistics. *Transactions of the Universities of Košice*. pp. 20-23.
5. Lemma, E. et al. (2002) *International Journal of Machine Tools & Manufacture* 42, pp. 781-789.
6. Monka, P., Monková, K. (2000) Intensification of cutting parameters contra surface roughness. *New ways on manufacturing technologies*, pp. 271-274.
7. Vasilko, K., Vasilková, D. (2000) *Methods of improving of the surfaces morphology*. TU of Košice, pp. 120