J. VALÍČEK, S. HLOCH, I. SAMARDŽIĆ, M. KUŠNEROVÁ, M. ZELEŇÁK

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INFLUENCE OF TRAVERSE SPEED ON SURFACE IRREGULARITIES CREATED BY THE ABRASIVE WATERJET

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The paper deals with the calculation of the optimal traverse speed for different types of materials, which is very important for predication, imaginings and dimensioning of technological factors and selection of the materials with the aim to increase of surface quality at abrasive waterjet cutting (AWJ) technology. The surface irregularities of the experimental used materials AISI 304, AISI 309 have been measured by non-contact shadow method. New empirically compiled equations of the influence of the traverse speed on tensometrical state of cut, deformation resistance of material and surface roughness *Ra* are at AWJ cutting available.

Key words: Abrasive Waterjet, Surface Quality, Traverse Speed, Material

Utjecaj poprečne brzine na nepravilnosti površine dobivene abrazivnim rezanjem vodenim mlazom. Rad se bavi proračunom optimalne brzine rezanja za različite vrste materijala, što je vrlo važno za predikaciju, osmišljanje i dimenzioniranje tehnoloških čimbenika i izbor materijala s ciljem da se poveća kvaliteta površine reza tehnologijom abrazivnim vodenim mlazom (AWJ). Površinske nepravilnosti eksperimentalno korištenih materijala AISI 304, AISI 309 su mjerene bezkontaktnom metodom sjene. Dobivena je nova empirijska jednadžbe utjecaja brzine na tenzometrijsko stanje rezne površine, deformacijsku otpornost materijala i površinsku hrapavost *Ra* kod AWJ rezanja.

Ključne riječi: abrazivni vodeni mlaz, kvaliteta površine, brzina rezanja, materijal

INTRODUCTION

The economic effectiveness of production systems for waterjet cutting and subsequently the economic competitiveness are mainly conditioned by the cutting performance and the quality of cutting surface. The paper is continuing of the study [1] where is described the method how to obtain the parameter C from RMS value for appropriate on-line control. Surface quality depends exclusively on AWJ tool geometry whereas an irregularity appears as the result of theoretical roughness though with bigger or lesser occasional roughness provoked by the many factors [2]. One of the most important and technologically best-more easily controlled technological factors in relation to roughness is traverse speed v [$mm.min^{-1}$] of the cutting head. Knowledge of the traverse speed influence and the other technology factors on surface quality is important for optimal estimation cutting power, high quality and cutting depth. Optimal factors set, is necessary for technological regime optimization from the quality point of view and the total performance of the referential technology.

J. Valíček, S. Hloch, M. Kušnerová, M. Zeleňák, Faculty of Manufacturing Technologies TU Košice with a seat in Prešov, Slovakia, I. Samardžić, Mechanical Engineering Faculty J. J. Strossmayer University of Osijek, Slavonski Brod, Croatia

REFERENTIAL TECHNOLOGY

The knowledge of the traverse speed influence and the others technological factors [2-5] on surface quality is important for determination of technological factors optimal composition, for optimization of technological regime from the point of quality view and total performance. If we performed any theoretic analyses of results, the samples must be realized in uniform technological regime. By means of AWJ technology, which was provided investigation of samples, regard as fundamental and comparative (referential) and in calculation we refer coefficient technology $K_{tech} = 1$ [6-7]. Every change in referential technology then corresponds with adequate, mathematically derivable and definable non-dimensional coefficient of technology $K_{tech} \neq 1$. Up to now referential technology has not the analytical model that is reason why we propose it.

OPITMAL TRAVERSE SPEED PROPOSAL FOR A MATERIAL

A lot of statistical and analytical studies of results of measuring various materials carried out by us [1,6] lead to the conclusion that the distribution of characteristic height and longitudinal parameters of roughness, or waviness into individual zones in the direction of growing depth of cut shows certain regularities. The influence simultaneous changes of the main technological factors compared with referential can be expressed by the complex technology coefficient K_{tech}. The complex coefficient of technology is expressed as product of partial components of the traverse speed K_v, the abrasive K_{abr} and pressure before an orifice K_p influence. The fact is, that these partial coefficients will have different values according to influence on different parameters, e.g. K_{vRa} and for estimation of the traverse speed influence on roughness Ra, or K_{vm} and influence of speed on alteration of material workpiece etc. The values that are selected according to experience, and published presumption, is possible to express by means of analytical or mathematical-statistical way. Behind analytic optimal expression way of the technology complex coefficient and its estimation and determination as the product of single coefficient, they are defined as the rate of technologically optimal values referential on machined material. The equation for calculation of optimal factors (e.g. traverse speed of cutting head) is not simply theoretic derivable for concrete material, that is why the empirical knowledge is used in technical practice. For orientation calculation, we proposed the empirical relation for optimal traverse speed of cutting head v_{opt} for different material that can be mathematically expressed by the equation (1):

$$v_{opt} = \frac{k_1}{E_{mat}^{0,5}}, \tag{1}$$

where: $k_1 = 0{,}0581 \cdot 10^6 \sqrt{\frac{kg \cdot m}{s^4}}$.

The remark: interpretation of converter coefficient k_1 related to coefficients in technical practice given to use for cutting material (relation appear from empiricism obtained only for steels AISI 309). At changes of traverse speeds of the cutting head come to creep of the material, which subsequently leads to fundamental improvement alteration of modulus of elasticity. Then we can express the influence of the traverse speed on surface roughness by the equation (2):

$$K_{vRa} = \frac{v_{sk}}{v_{opt}} = \frac{v_{sk}\, E_{mat}^{0,5}}{k}, \tag{2}$$

or expression of the influence traverse speed on mechanical alteration of material by the equation (3):

$$K_{vm} = \frac{\log(v_{sk})}{\log(v_{opt})}. \tag{3}$$

Generally without close explicit specifications will be the influence of abrasive quality expressed by equation (4):

$$K_{abr} = f\left(\frac{A_{brsk}}{A_{bropt}}\right), \tag{4}$$

respectively the influence of hydraulic pressure before the nozzle (5):

$$K_p = f\left(\frac{K_{psk}}{K_{popt}}\right). \tag{5}$$

The complex coefficient of technology expressive summarily influence of partial changes different factors on surface roughness is given by equation (6):

$$K_{techRa} = f(K_{vRa}, K_{abrRa}, K_{pRa} \ldots), \tag{6}$$

or on mechanical alteration of the material (7):

$$K_{techm} = f(K_{vm}, K_{abrm}, K_{pm} \ldots), \tag{7}$$

where:

K_{vRa} - the coefficient of technology for the influence changes traverse speed of cutting head on surface roughness,

K_{abrRa} - the coefficient of technology for the influence changes type of abrasive on surface roughness,

K_{pRa} - the coefficient of technology for the influence changes type of abrasive on surface roughness,

K_{vm} - the coefficient of technology for the influence changes of traverse speed of cutting head on alteration of material,

K_{abrm} - the coefficient of technology for the influence changes type of abrasive alteration of material.

Analytical solution of surface roughness dependence in trace of cut on the traverse speed $Ra = f(v)$ indeed includes of influence of the other variables on topographic state of surface. This variable is especially alteration of mechanical properties of material and the influence of cutting depth. In our case, it will represent mechanical state of material his modulus of elasticity E_{mat}, the alteration value will be labelled v express $E_{matalt} = f(E_{mat}, v)$. Generally implicit expressed equation for development of roughness in trace of cut will be $Ra = f(v, E_{matalt}, h)$. The material parameter E_{mat} is included in empirical equation (1) for calculation of the optimal traverse speed v_{opt}. Combination of both these equations we obtain a new relation between technologically important parameters. Very often discussed question of relative hardening, respective creeping of material in cut e.g. demonstrative expression E_{mat} by the help of combination introduced of equations. Such calculated material parameter already has not tabular character of material constant E_{mat}, but has the alteration values with mark E_{matalt} depending on selection of traverse speed v and the other technological parameter including of surface roughness (8):

$$Ra = (-10) \cdot (1 - 10^{12} E_{matalt}^{-2} / (10^{12} \cdot E_{matalt}^{-2} - h)) \tag{8}$$

where: $$E_{matalt} = \frac{k_2}{\left(\frac{\log(v_{popt}) v_{popt}^2}{\log(v_p)}\right)} \tag{9}$$

where: $k_2 = 0{,}00342 \cdot 10^{12}\ kg \cdot m^{-3}$.

The remark: interpretation of converter coefficient k_2 again relate with coefficients in technical practice existent used cutting material (relation start from empiricism obtained only at measurement of steel AISI 309). The changes of traverse speeds of cutting head lead to creep-

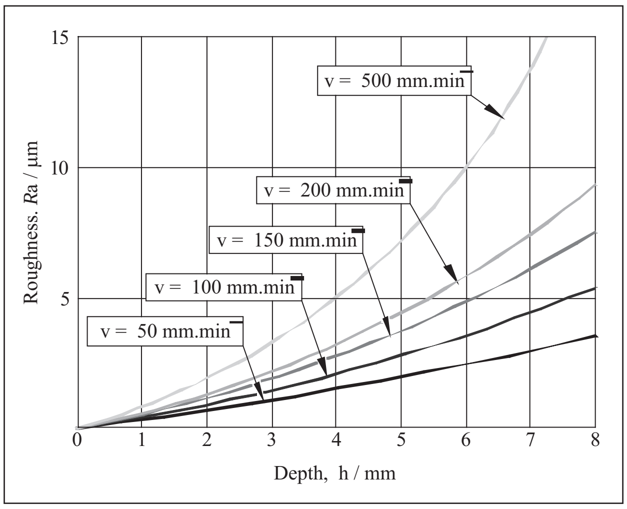

Figure 1 Theoretical distribution of roughness in trace of hydroabrasive cut for *Ra* = (*v*, E_{mat}, E_{matalt}, *h*); E_{mat} = 205 GPa; *h* = 8 mm

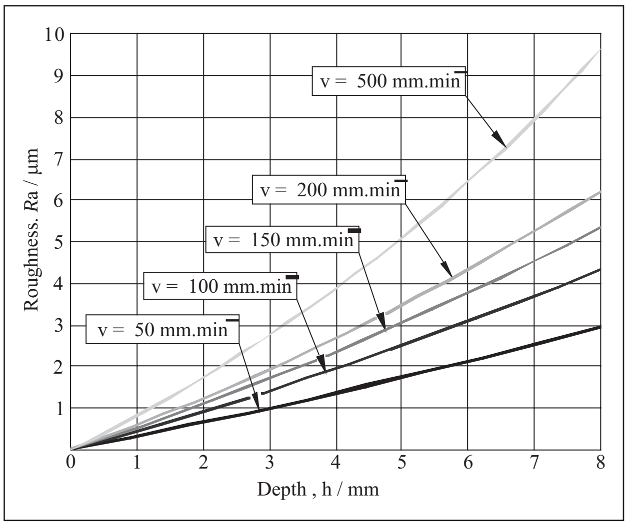

Figure 2 Theoretical distribution of roughness of cut surface for *Ra* = (*v*, E_{mat}, E_{matalt}, *h*); E_{mat} = 195 GPa; *h* = 8 mm

ing of the material, which subsequently leads to substantial improvement alteration modulus of elasticity.

The equation (8) specify by concrete, in our case values -10 and 1 size of longitude, whereas empirically used value 1 012 represent value E_{mat}, in face of that have with alteration value modulus of elasticity relate.

If we substitute in equations (8), (9) v_{opt} the values of the traverse speeds 50, 100, 150 and 200 mm·min^{-1}, we can verify the tightness of measured values (see. e.g. Figure 1 for steel AISI 309, E_{mat} = 205 GPa). In addition, for prediction calculation it has been used the value of 500 mm·min^{-1}. Possibility of such prediction calculation for the selected traverse speed and for the target material is very important for technologist, because it relate with achievement of required of the surface quality of cutting wall, needed of cutting depth, as well as with productivity and economies production. Similar theoretical equations for prediction of the state cut has not been derived, it is used only the technologist experience. Problems with quality and productivity occur with the changes of machined material. The obtained results for traverse speeds v_{opt} and materials AISI 304 (195 GPa), and AISI 309 (205 GPa), are illustrated on the Figure 1 and on Figure 2. On Figure 3 is prediction calculation to the depths *h* = 23 mm for material AISI 304 (195 GPa).

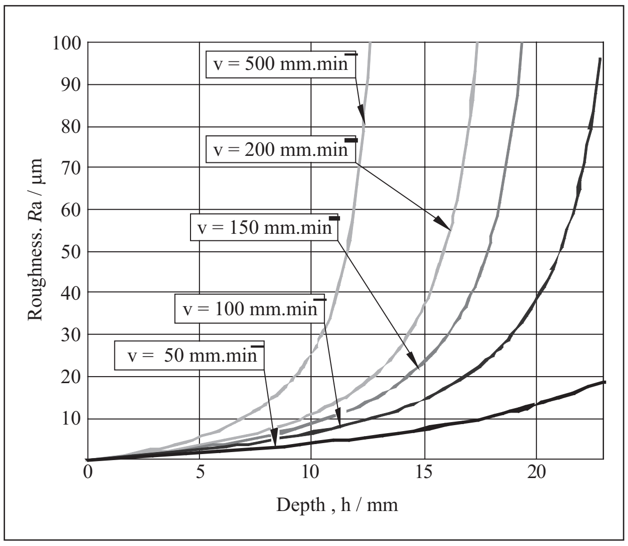

Figure 3 Theoretical distribution of roughness in trace of hydroabrasive cut for *Ra* = (*v*, E_{mat}, E_{matalt}, *h*); E_{mat} = 205 GPa; prediction calculation to depth *h* = 23 mm

On Figure 3 is prediction calculation to the depths *h* = 23 mm for material AISI 304 (195 GPa). The Figure 3 illustrates the intensity growth trace of roughness according to selection of the traverse speed *v*. With the raising of the traverse speed, the economic indicator is raised, but on the other hand, the surface quality is decreased, and proportionally the cut depth also decreased.

CONCLUSIONS

The traverse speed is one of very important and technological easily controllable factor in relation of surface roughness. Knowledge of the traverse speed influence and the other AWJ factors on surface roughness is important for the optimal technological factors set estimation, for optimization of technological regime from the aspect of quality and total performance. In current manufacturing practice control of the traverse speed at material cutting, is realized according to subjective experience of the technologist.

New equations were derived for numerical expression of the traverse speed influence *v* on tensometric state of the cut, on deformation material resistance and on surface roughness *Ra*. According to the authors, it is important for AWJ technology to derive relations for formulation of influence the traverse speed *v* on tensometrical surface state, deformation material resistance, surface roughness *Ra* and other specified surface geometric parameters. The equations for determination of the optimal traverse speed (1) represent such traverse speed of cutting head v_{opt} at which give out to tensometrical optimal mechanical alteration material with the aim to obtain required quality and cutting depth at economically optimal traverse speed. The equations were experimentally verified for metal materials. Further experiments will be provided in order to derive the prediction quantify equations that will be verified adjusted for various types of the important technological factors such pressure, abrasive mass flow rate and diameter of the focusing tube.

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