

# INTERPRETATION OF THE ROUGHNESS MEASUREMENT SPECTRA OF THE SURFACE PROFILES

## ИНТЕРПРЕТАЦИИ СПЕКТРОВ ИЗМЕРЕНИЯ ШЕРОХОВАТОСТИ НА ПОВЕРХНОСТИ ПРОФИЛЕЙ

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**Abstract:** The paper deals with the estimation and interpretation of the roughness measurement spectra of the surface profiles. The analysis of the surface roughness has been done using the original optical measuring method using the laser light reflected on the surface prepared by abrasive water jet cutting. The surface roughness profiles have been carried out through the scanning the surface through the laser beam reflected on the different places of the surface.

**KEYWORDS:** ABRASIVE WATERJET, SURFACE TOPOGRAPHY, ROUGHNESS

### 1. Introduction

Undoubtedly, machining of metal materials by abrasive water jet (AWJ) is very useful [1], [2], [3]. The lack of full understanding of the cutting process is still a frequent problem. However, abrasive water jet being applied for machining of metals usually creates the surface with random dimplings and other defects with characteristic shapes, e.g. sharp edges due to turning of particles into microcrystal structure. Previously development two-scale model of roughness is appropriate when a characteristic dimension of a lighted small area is comparable with the correlation length of the low-frequency component of surface roughness. The complex roughness value corresponding to the rough surface can be divided into at least two components, the high-frequency one equivalent to roughness, and the low-amplitude one equivalent to waviness. Existence of this model makes possible to pick up mentioned information (roughness and waviness) incorporated in an average scattering field becoming from various tilted areas on the surface [4], [18], [19], [20], [21], [22], [23].

### 2. Geometrical specification of surface structure

Any technological method used for the creation of surfaces in technical fields leaves unevenness, which has a fundamental importance for the function of these areas. The unevenness on the surface represents a cubic (space) formation which can be solved by reduction into the plane of cut though a plane vertical to the surface (Fig. 1). In the cutting plane a new profile is created which provides a fundamental source of information for judgements of surface structure [1], [2], [21], [23].

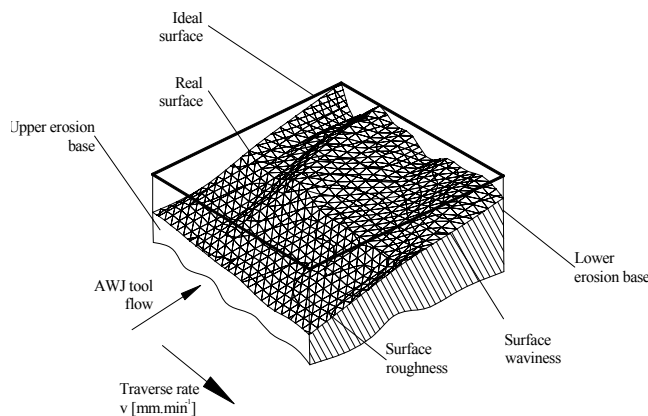


Fig. 1 Model of the surface created by AWJ

The method of objective judgements and evaluation of the most important component of surface structure – roughness – has a long history. At first a sinusoidal model of unevenness was used, when a

quantity  $H_{SK}$  (analogy of the effective value of alternating current) was used as a parameter for evaluation. Later, a parameter  $R_a$  (analogy of the mean value of alternating current) was preferred together with some further parameters. In connection with a new conception of a geometrical specification of production (GPS-geometrical product specifications) some more sophisticated systems for the assessment and evaluation of surface structure was created. This is the system which is regulated by currently valid standards. The surface structure is divided into components according to the pitch of overall unevenness. There are three components in the surface structure: a component with the smallest pitch creating roughness of surface, a component called waviness of surface and a component with the biggest pitch of unevenness, called the basic profile (Fig. 2).

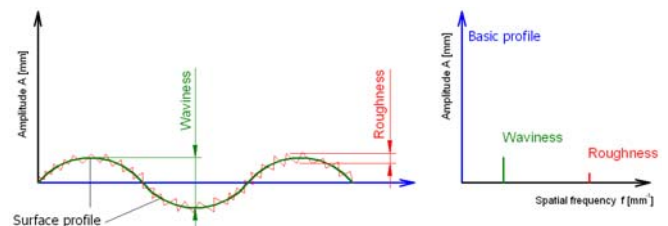


Fig. 2 Surface profile with amplitude fluctuations and amplitude spatial frequency spectrum

### 3. Experimental realization of apparatuses

According to [4] the reflection  $R$  depends primarily on quantities characteristic for radiation (wavelength  $\lambda$  or frequency, intensity of incident radiation  $I_o$ , pulse duration  $t$ , polarization of radiation  $p$ ) next on material characteristics such as a specific electric conductivity  $\gamma$ , index refraction  $n$ , permittivity  $\epsilon$  and arrangement geometry described by incident angle  $\epsilon_i$  and surface roughness  $R_a$ , and it can be implicitly expressed:

$$R = R(\lambda, I_o, t, p, \gamma, n, \epsilon, \epsilon_i, R_a) \quad (1)$$

The surface reflectance is function of topographical functions expressed in equation (1) by the parameter  $R_a$ . Provides that light wavelength  $\lambda$  meets the condition to be greater than middle quadratic values of the surface topographic fluctuations (RMS – Root-Mean-Square) the RMS is possible to express the relation for example by equation according to [5]:

$$RMS = \frac{1,52\lambda\sqrt{\log_{10}R}}{4\pi} \quad (2)$$

The values of RMS we use also to the decomposition of the whole topography function of surface on individual components of lower order. It is necessary the whole profile of surface divide by using

fourier transform on waviness of surfaces function, grooving, slotting and roughness. The whole profile is then integrated profile from specific characterized construction sub aspects (in the geometric and function view). For better characterization and determination of the stochastic and periodic component in practice the autocorrelation function of the whole topographical profile has been used for analyses of signals. Classification of surface parameters through two components (the stochastic and the periodic ones) is proposed in [6]. The motivated into this conclusion by the fact that the short-wave unevenness, especially roughness, is caused by the stochastic character of disintegration induced by particular abrasive particles of the AWJ. On the contrary rising of waviness they attribute to the periodical character of energy influences with essentially lower frequencies affecting the disintegration process (fluctuation of technological parameters AWJ, vibration of machine and work-piece etc.) [6], [7], [10], [11], [12], [13]. The evaluation of the autocorrelation function provides the tool for mathematical manipulation with the topographic function of the geometrical form of surface and enables to find so called autocorrelation length and autocorrelation coefficient.

A basic set up of the shadow visualisation method is sketched in Fig. 3. The CCD camera with 1090 x 1370 pixels is used for scanning and recording of the intensity of the reflected off the surface. Observed surface is illuminated at a small oblique angle by a beam of collimated light. The shadow visualisation effect rises from a change of a surface reflectivity with the angle of illumination. In this type of illumination not only the sharp marked dimples and other defects easily recognizable but also a typical waviness created by abrasive water jets can be observed. Furthermore, the 3D topography can be evaluated. Since the orientation and curving along jet traces is extremely important for evaluation of quality of the abrasive waterjet mechinning, the reliable detection of shadows is especially important for a characterization of the surface topography [8], [9], [10], [11].

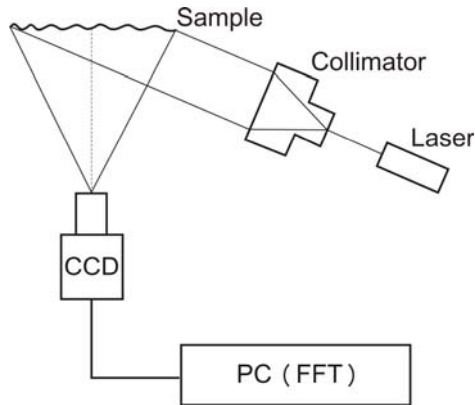


Fig. 3 Basic set-up of optical method for shadow visualization

#### 4. Results and discussion

The method mentioned above has been used for measuring of profiles on metal samples (steel AISI 309) with dimension 20 x 20 x 0.8 mm. The results convinced us that there is possible to detect and quantitatively determine both the stochastic and periodic character of surface topography and so quantify assessing height anomaly value and their fluctuations. The obtained experimental results show that surface correlation length increases along a trace of abrasive water jet. Correlation length represents the horizontal property of a surface profile. The stochastic component in the upper part the cut is much bigger than in the lower part. The results are expressed in Fig.4, Fig.5, Fig.6, where the perceptible qualitative division of zones of cut onto the stochastic zone and the periodic one is evident. The analytical analysis of the autocorrelation function yields information about autocorrelation length as function of pitches of surface unevenness (it corresponds to the wavelength of surface topography).

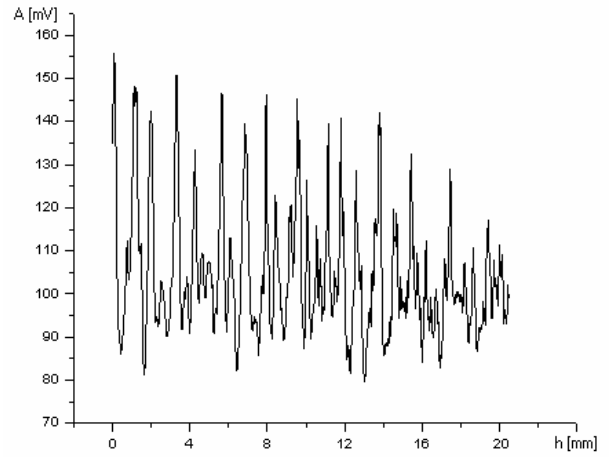


Fig. 4 Signal of the surface roughness in the most deteriorated grooved zone, where A is amplitude of the signal topography and h is depth of cut.

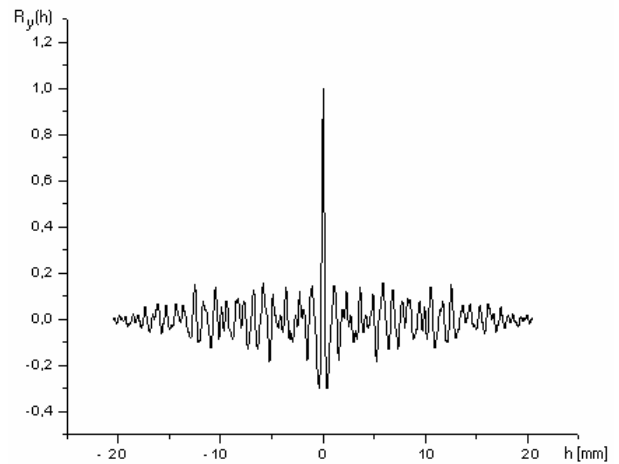


Fig. 5 Autocorrelation function obtained from surface of the most deteriorated grooved zone

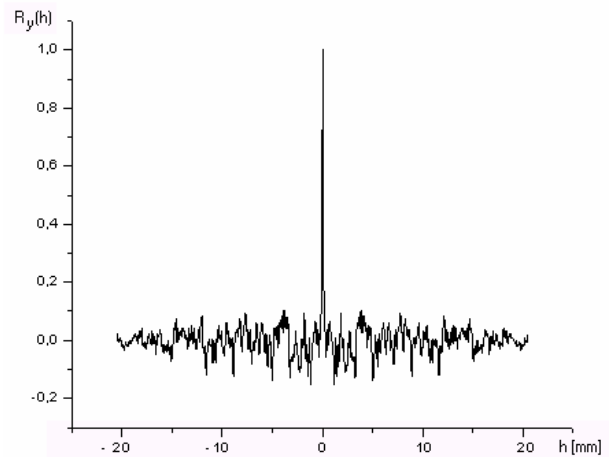


Fig. 6 Autocorrelation function obtained from non-grooved zone.

#### 5. Conclusion

The measuring non-contact method based on the optical principle was proposed. It seems to be the appropriate one for such a purpose because the experiments are promising. The attempt to improve the quality of production of the AWJ machining will be made after the technical finishing of the prototype. From performance analyses oneself elaborative, of which result, that smooth cut together allows achievement bigger cutting depth in a given matters. Achievement high cut depth and smooth cut is possible reached by optimal

dimension of technological factor AWJ with significant impact on final quality of workpiece.

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