

Shadow method for the evaluation of surface created by hydroabrasive dividing of materials

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Abstract

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The contribution deals with the analysis of the optical data obtained from the surfaces generated by hydroabrasive dividing of materials. The samples of different materials were prepared at the Academy of Sciences of the Czech Republic. The comparison of further results performed between the commercial contact profilometer HOMMEL TESTER T8000 and the contactless shadow method developed included its calibration. On the basis of the optical data analysis, the results evaluated especially the height irregularities of the surface topography caused by hydroabrasive cutting planes. The evaluation of the surface topography generated by abrasive waterjet was realised via spectral analysis. The amplitude-frequency analysis of the signals generated on surface topography was mainly realised.

Keyword: disintegration of materials; optical method; roughness; measurements

While the engineering cutting technologies generally make mirror surface reflections, the hydroabrasive dividing of materials makes diffusive surface reflections. The topography of the hydroabrasive generated surfaces records significant diversity in the heights of amplitudes and their waves lengths. Thus, the development of the optical method is focused on the metrological compatibility of optical and mechanical profilometry methods, i.e. the op-

tical method will evaluate the basic parameters of the surface roughness according to the engineering standards. It is the shadow method which was selected from all the methods to realise the experiment because this method is able to fulfil the experimental demands. The experimental results of the commercial contact profilometer HOMMEL TESTER T8000 (Hommerwerke GmbH, Villingen-Schwenningen, Germany) were used for further

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Table 1. Technological parameters of samples

Technological parameter	Value
Liquid pressure (p , MPa)	300
Water orifice diameter (d_o , mm)	0.25
Focusing tube diameter (d_a , mm)	0.8
Focusing tube length (l_a , mm)	76
Abrasive mass flow rate (m_a , g/min)	250
Standoff distance (L , mm)	2
Material thickness (h , mm)	8
Traverse speed (v_p , mm/min)	50, 100, 150, 200
Abrasive size (–, MESH)	80
Abrasive material (–)	Garnet Barton

analysis. The main aim was to use the proposed methodology for measuring and evaluating the surface topography generated by hydroabrasive dividing of materials with the aim of proposing semi-automatic and automatic operations of the surface quality estimation. Thus, it is necessary to process the bank of input and output parameters of hydroabrasive dividing and to propose the criteria for on-line operation (HASHISH 1984; VALÍČEK 2007a).

Hydroabrasive dividing of materials

Dividing of materials causes hydroabrasive fission of the material including possible material destruction. The impact of the material particles has elastic-plastic characterisation. In the case of the plastic dominance, the particles can be constrained in the material in the dividing flow as well as in the cutting plane. The dividing effect is then based on

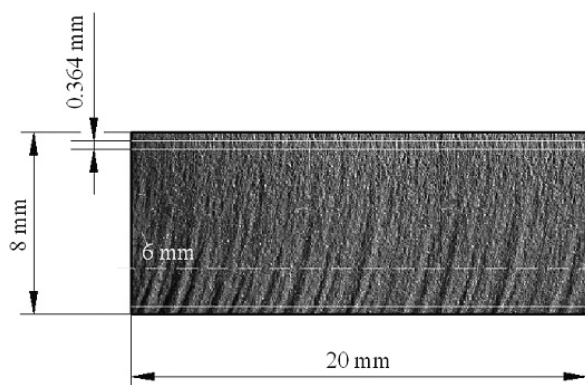


Fig. 1. Illustration of measuring lines on steel sample (ČSN 41 725, 1991)

the cumulated particles with certain quantity and traverse speed. The size and the shape of the machined particles depend on the amount of the cutting planes and the trajectory of their movement. The parameters which influence the process are: the speed of element, abrasive mass flow rate, wall sharpness, hardness of element, size and shape of element, physical and mechanical properties of work-piece. The material removal then depends on the combination of the factors mentioned. HASHISH (1984) reported on the interdependence of the removal size, elements speed, wall sharpness for plastic and brittle materials as well as the hardness and size of the abrasive elements.

The creation of the machined particles is then based on the movement trajectory and the speed. The speed can be divided into translational and rotational parts. HASHISH (1984) and other scientists TICHOMIROV and GUENKO (1984), BLICKWEDEL et al. (1990), ZENG and KIM (1990), GUO (1994), BRANDT et al. (2000) worked on the scanning of the moves by high speed cameras. Hutchings described and defined two types of rotation for the rotational part of the speed, i.e. rotation in traverse speed and backward rotation towards traverse speed. He observed different behaviour of plastic materials and brittle materials. Brittle materials were plastically changed whereas plastic materials were reinforced. He also explained that the abrasive effect of abrasive water jet (AWJ) is mainly determined by inertial and resistant forces of the abrasive particles and their deformation and disintegration overtake hydrodynamic forces. That explains the abrasive scratch of materials disintegration.

MATERIAL AND METHODS

Thirty samples of different materials were prepared at the Academy of Sciences of the Czech Republic. The size of each material was $20 \times 20 \times 8$ mm (Fig. 1). The samples were made with PTV-37-60 Pump (PTV, Ltd., Hostivice, Czech Republic) according to the parameters given in Table 1. The traverse speed of the cutting head was the only variable parameter, i.e. 200, 150, 100 and 50 mm/min.

Each material and each side of the samples was measured in 22 measuring lines. Each measuring line provided the information about the signal of the light and shadow by means of a CCD camera (ILC, Bratislava, Slovak Republic) VALÍČEK et al. (2007b).

A laser diode with the performance of W/650 nm was used in the experiment. The shadow visual effect

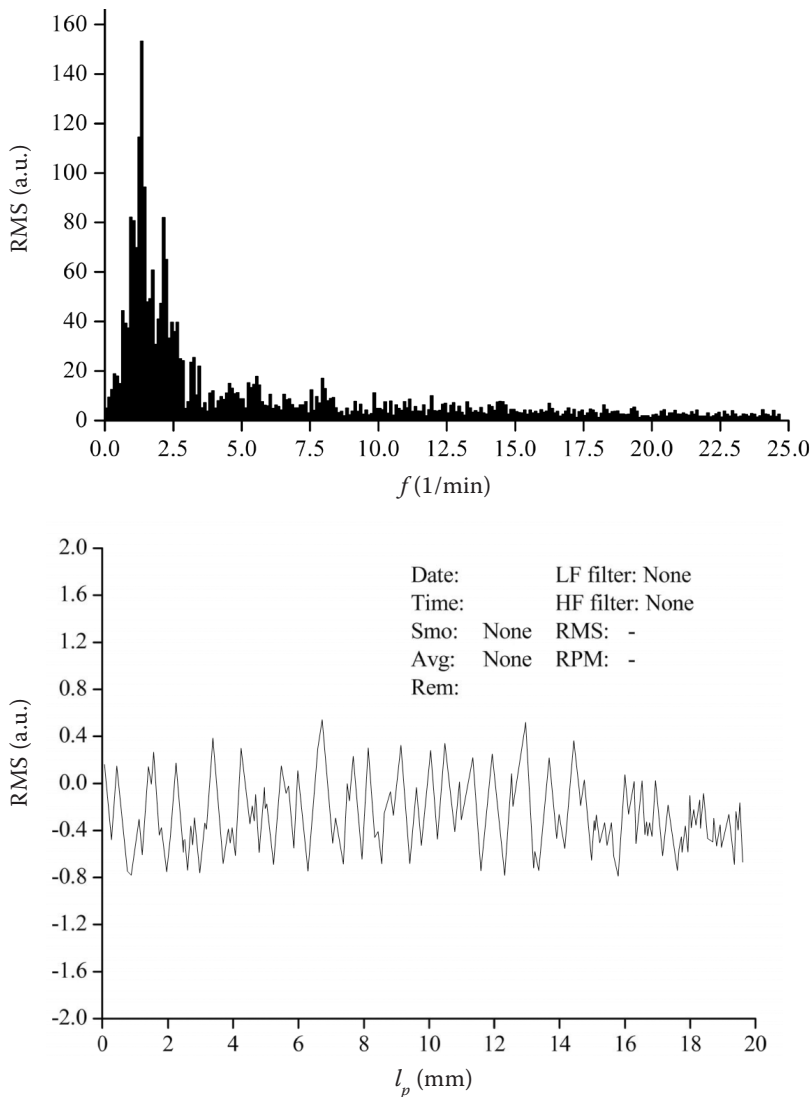


Fig. 2. The signal obtained in sampling the intensity distribution from the surface picture obtained by CCD camera

also depends on the illumination angle. The beam angle allows to view clearly the elevations and depressions of the surface topography which is related to the typical waviness of hydroabrasive dividing of materials. The sample illumination was realised under 15° and the changes were detected by means of a CCD camera with $1,090 \times 1,370$ pixels.

Fig. 2 illustrates a typical signal obtained by intensity distribution sampling from the surface as gained by the CCD camera.

The signals were processed by Vibroanalyser program (ILC, Bratislava, Slovak Republic). The program transfers the signals via Fourier Transform (FFT) from the time area to the amplitude-frequency spectrum. The spectrums involve the areas in which waviness and roughness are concentrated. That is why the zonal filtration of amplitude-frequency spectrum was realised (Fig. 3), i.e. the spectrum was divided into six frequency zones whereby the selected frequency intervals

simulated to contact profilometer cut-off to provide the topography of samples.

RESULTS AND DISCUSION

Results comparison between commercial method and shadow method

The results of the shadow method could be compared with the results of the commercial method. The results of the shadow method measuring could be confronted with the results of the contact profilometer HOMMEL TESTER T8000 according to the amplitude-frequency spectrums. The signal from 6 mm was selected to present the differences between these methods.

Fig. 4 illustrates a twelve times extended cutting plane of hydroabrasive dividing. From the signal, the amplitude-frequency spectrum was recorded.

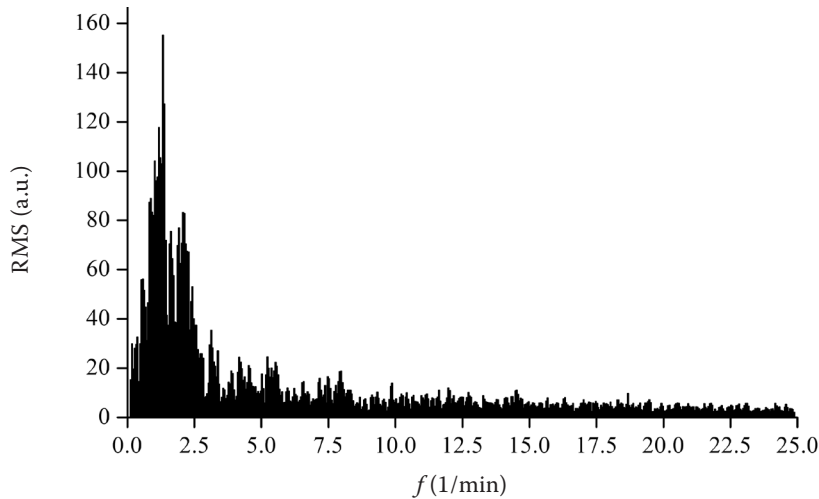
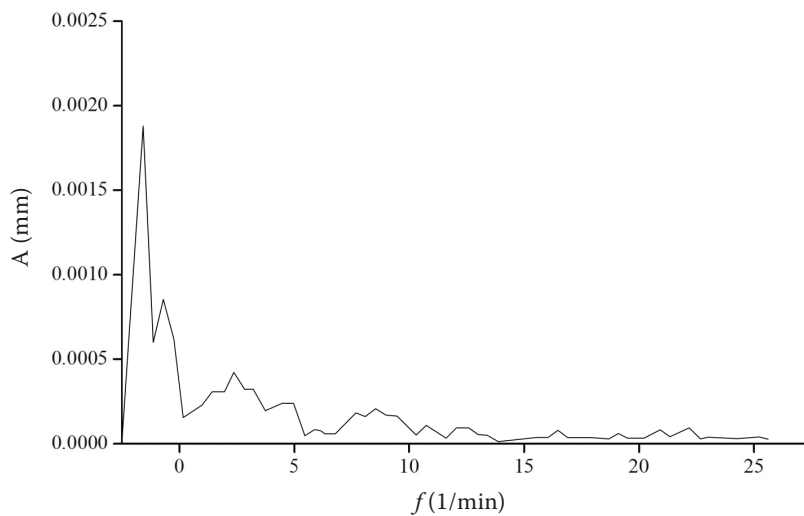


Fig. 3. Amplitude-frequency spectrum of the surface obtained from one representative measured line at 6 mm depth from surface with distinguished frequency bands



The localisation can be seen of low-frequency components with the highest amplitude values from to the frequency band 0–2.5 1/mm definitely corre-

sponding to the waviness of the machined surface. The average value of this zone was approximately 1 l/mm which corresponded to the wave length λ of 1 mm. This can be confirmed directly on the sample and it also allowed a better understanding of the hydroabrasive dividing.

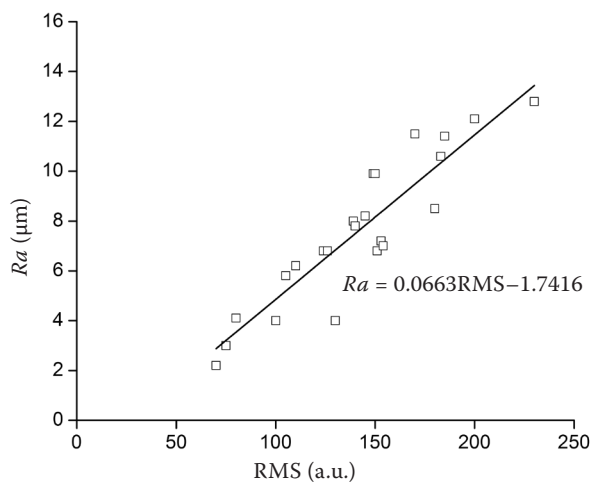


Fig. 4. Comparison of results between a) commercial method and b) shadow method

Calibration of the shadow method by contact profilometer

Based on the results and their confrontation with Ra and Rq parameters directly detected on the samples of the contact profilometer HOMMEL TESTER T8000, the RMS (Root Mean Square of reflected light intensity) was selected as the appropriate parameter for the surface topography of the samples machined by hydroabrasive dividing. The RMS parameter used in the shadow method enables to detect the fluctuation of the changes developed by the topographical principle of the sample surface.

It has been confirmed that the surfaces generated by hydroabrasive dividing of materials are not stochastic but are mostly periodical with a wide range of high amplitudes and their wave lengths. For the pitches and wave lengths, about 5,000 values of RMS parameters were measured and the calibration of primary signals was realised. After analysing the results (Figs 2 and 3) reached by the shadow method and after the verification with the commercial profilometer HOMMEL TESTER T8000 for steel ČSN 41 17241 (1980) and iron ČSN 42 2712 (1979), the RMS value was 0.05 Ra. The calibration function is shown in Fig. 4.

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