Calibration of Optical Method Prepared for Analysis of Cutting Edges Produced by Abrasive Water Jet

Jan Valíček
Institute of Physics
VŠB - TU Ostrava
jan.valicek@email.cz

Libor M. Hlaváč
Institute of Physics
VŠB - TU Ostrava
libor.hlavac@vsb.cz

Eva Janurová
Institute of Physics
VŠB - TU Ostrava
eva.janurova@vsb.cz

Juraj Chlpik
International Laser Centre
Bratislava
chlpik@ilc.sk

Abstract

The optical method appropriate for studying of the specific surfaces created by abrasive water jets has been assembled and tested. It is based on shadow visualization of random rough surfaces and it makes possible to obtain the shadowing function from distribution of light and shadows.

Introduction

The primary calibration of the newly prepared shadow optical method as non-direct one is performed by direct method, i.e. by contact profilometer [1], and above all through the norm parameter Ra. Moreover, calibration by optical way, which will be described below, was also realized. The reason for this solution rises from some typical problems with application of measurement method and with type of results obtained by contact profilometers including slowness and high measurement costs.

1 General description

The method of shadow visualization of quite coarse roughness/waviness is based on the optical observation and evaluation of aerial distribution of shadows as well as semi-shadows when an oblique illumination of the rough surface is applied [2]. The inspected surface is illuminated at a small angle typically between 10 and 20 degrees to the surface by a beam of the collimated light

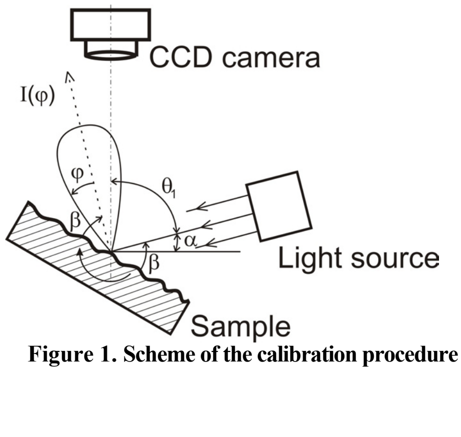

Figure 1. Scheme of the calibration procedure

(see Fig. 1). The laser diode 3 mW and 650 nm has been used in

experiments but an incoherent incandescent lamp has been also tested for such a purpose.

The shadow visualization effect is changing regarding surface diffuse reflectivity and the angle of inclination. At such an illumination the hills and pits at material surface are clearly visible and the typical waviness created in WJ/AWJ cutting process can be easily recognized. Changes in intensity distribution were detected by CCD camera with 1090 x 1370 pixels at 2/3” chip. Regarding requirements of a testing method the stand/off distance between the objective lens 1.4/50 mm and object surface has been adjusted to about 200 mm, thus creating a magnification 0.33 × of the CCD chip effective area.

2 Calibration process

Recording the image of the whole sample length (20 mm) the traces of intensity distribution were selected and analyzed by FFT analysis software (Fig. 2). The total number of 1024 samples is acquired in one line and then processed by Vibroanalyzer, version 2.3. The resolution ability was optimal for chosen cut-off and expected frequency level [3]. Summarized values were averaged and statistically processed along the whole length of cutting wall. The experiments were realized with red, green, near infrared and white light. Simultaneously, the profound analysis has been performed for optimization of the angle

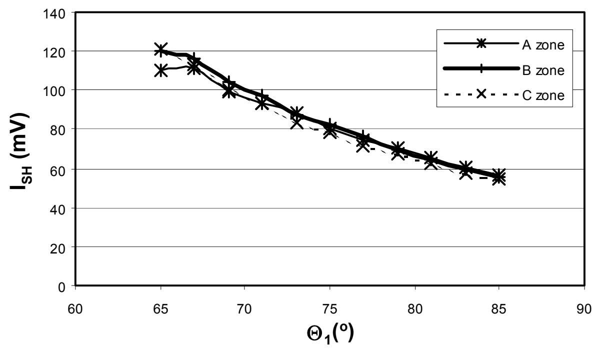

Figure 2. Curves of detected light intensity from zones A, B and C

of illumination of the surface. Considering specific features of processed surfaces results from each line has been obtained through averaging of values gained from 20 single measurements in the appropriate line. So the statistics along either WJ or AWJ stream should be satisfactory.

3 Discussion and results

Illuminated surface yields a determined distribution of light and shadows implying the topographic surface function. Shadows depending on slope of small areas and their scattering diagrams can be used for derivation of an approximative method for determination of ruling space frequencies (wavelengths at surface).

Development of a new optical method was aimed at qualitative identification of varying characteristics of unevenness at zones along the jet stream path. Nevertheless, some quantitative information can be also acquired. The shadowing function is experimentally assessed using a CCD camera detecting the integral reflectivity of the whole rough surface. Varying the angle of inclination, nearly linear angular dependence of the scattered light intensity was measured in tested range of the oblique angle of illumination. The calibration curves proved the identical trends independently of the observed zone of roughness.

The illumination of surface creates a determined distribution of light and shadows, referring to a topographic surface function. The scattering of a light intensity by inclined slopes causes a measurable diminution of intensity of reflected light. Shadowing theories assume that shadowing corrections could be incorporated into scattering theory by multiplying the scattered light intensity by a shadowing function. The shadows can be used as an approximate way, how to estimate the dominant spatial frequencies – surface wavelengths, because the average shadow size is a measure of the presence of this wavelength on the surface.

After calibration another analyses were performed with presented method. It has been used for measurement of profiles on metal samples with dimensions 20x20x0.8mm. The results convinced us that there is possible to detect and quantitatively determine both the stochastic and the periodic character of surface topography and so to quantify assessing height anomaly value and their fluctuations. 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 of the cut is much higher than in the lower part. However, irregularities producing surface roughness and waviness occur simultaneously, roughness is often superimposed over waviness. Therefore the more widely spaced repetitive waviness deviations must somehow be factored out of roughness evaluations in accurate measurements. Then the surface can be modeled through two independent components: a high-frequency small amplitude one (roughness) superimposed on a low-frequency large amplitude one (waviness). So roughness surface is tilted by waviness one on which it is superimposed, thus affecting the angle of incidence of the illuminating light.

Conclusions

Selection and designing of a new optical method based on shadow visualization of topography of surface unevenness overrule the stage of verification and validation of function reliability. The ability to identify topographic zones on surfaces cut by water and abrasive water jets was proved and calibration of method enables to determine the surface quality with sufficient precision both qualitatively and quantitatively. Method is prepared for both description of disintegration mechanism at selected technological parameters of AWJ and determination of main measured and controlled quality parameters of machined surfaces of cutting edges.

Acknowledgement

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