How to cite this article:

Author: Czesław Łukianowicz

Title of article: „Zastosowanie technik przetwarzania obrazów do identyfikacji śladów obróbki ściernej” (“Identification of machining marks on abrasive treated surfaces, using image processing techniques”)

Mechanik, Vol. 91, No. 11 (2018): pages 1020–1022

DOI: https://doi.org/10.17814/mechanik.2018.11.181

Identification of machining marks on abrasive treated surfaces, using image processing techniques

Zastosowanie technik przetwarzania obrazów do identyfikacji śladów obróbki ściernej

CZESŁAW ŁUKIANOWICZ *

The principles of selected image processing techniques based on Fourier, Radon and Hough transformations are presented. The techniques can be used to quick identification of the machined marks on surfaces after abrasive machining. Example of software that allow the identification of machined marks is shown.

KEYWORDS: image processing, machined marks, Hough transform, adaptive filters

In abrasive machining processes, due to the impact of the abrasive tool with the surface on the machined surface, characteristic traces of machining are created. The shape and dimensions of these traces depend primarily on the method and parameters of machining, the kinematic system and stiffness of the machine tool, the type and properties of the abrasive tool, as well as on the material and the shape of the work surface. When observing the surface, you can identify the traces of machining created as a result of the last operation, and sometimes also traces of pre-treatment.

The identification of machining marks is understood in a general way in this work. It consists in recognizing specific traces and then qualifying them to a specific group, distinguished due to certain properties and properties such as shape. Sometimes, in addition to the identification of machining marks, surface identification and assessment are made.

Observation of the surface is generally carried out using a variety of microscopic techniques. This is due to the strive for thorough examination of small areas of the surface. Modern microscopes allow not only for the digital recording of images, but also for their processing and analysis.

The article briefly examines image processing techniques that allow to distinguish characteristic machining traces. Examples of the use of some of these techniques to identify and analyze traces of machining of abrasive surfaces, e.g. ground surfaces, are also given.

Fundamentals of machining traces identification

Residual marks remain on the finished surface. A variety of methods can be used for the overall assessment of the geometric structure of the surface with processing marks, e.g. using contact profilometers or optical systems [1].

* Dr hab. inż. Czesław Łukianowicz (czeslaw.lukianowicz@tu.koszalin.pl) – Katedra Inżynierii Produkcji Politechniki Koszalińskiej

If it is necessary to identify and evaluate individual machining marks or sets of such traces, microscopic methods supported by computer image processing and analysis are most useful.

Typical machining marks have a specific location and characteristic shapes that may be similar to such geometric objects as straight line sections or circles. In the microscopic images of the treated surface, the disturbing factors that occurred during processing are more or less clearly visible. In order to analyze them, it is necessary to carry out preliminary processing of images and extract those elements of images that belong to the characteristic traces of processing.

This operation – called the identification or recognition of traces of processing – boils down to finding out which objects with characteristic shapes describing typical machining tracks are present in the image of the surface being worked on.

General theory of the shape identification of objects, based on comparing the so-called shape descriptors, is presented in paper [2]. Most often, the identification of the shape of objects in an image is based on the application of Hough's transformation [3, 4].

An image in which various objects appear, including searched objects, is subjected to pre-processing, the main purpose of which is to detect the edges of objects. Hough's transformation is a representation of the plane of the image in the space of parameters describing the shape and location of the object sought. The idea of this transformation in the application to identify the shape of objects, which can be traces of processing, consists in replacing the detection of objects with a specific shape directly in the surface image, detection of peak values (peaks) in the parameter space, also called Hough space and the space of accumulation .

The parameter space is divided into cells that form a multidimensional array. In it, the results of the so-called vote. For each cell and its neighbors, the algorithm determines if the edge of the object has sufficient weight at this point. If so, the algorithm calculates the line parameters and, by "voting", increases the value in the cell corresponding to these parameters. Significant values accumulated in a given cell are a testimony to the fact that in the image subjected to Hough transformation there is an object with a shape and position, whose parameters are determined by the coordinates of a given cell in Hough space.

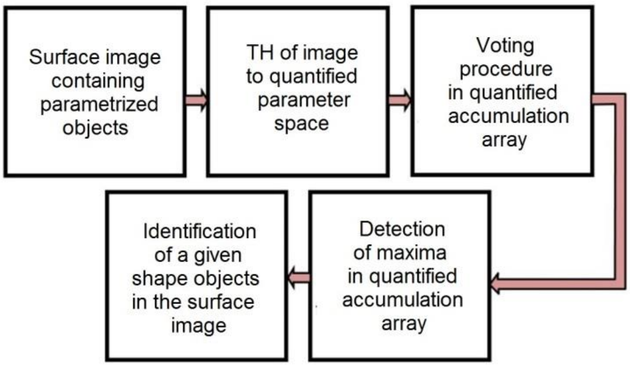


Fig. 1. Block diagram showing individual stages of the Hough transformation (TH) in the application to identify the shape of a parameterized object

The stages of the Hough transformation used to identify the parameterized object are shown in fig. 1.

If in the image of the surface of arbitrary rectangular shapes, for example straight lines of surface abrasion, such as grinding or glazing, they can be identified by means of Radon transformation or Hough transformation, which in this case is a special case of integral Radon transformations [3–5]. Both the Hough transformation and the Radon transformations are then based on the observation that the straight line which in the Cartesian 0*xy* coordinate system is described by the directional equation:

$$y = ax + b \tag{1}$$

It can also be written using the so-called normal equation:

$$r = x\cos\theta + y\sin\theta \tag{2}$$

where: *a* – directional coefficient of the straight line, *b* – ordinate of the point of intersection of the line with the axis 0*y*, *r* – distance of the straight line from the beginning of the 0*xy* coordinate system, θ – angle between normal and straight line and axis 0*x*, as shown in fig. 2.

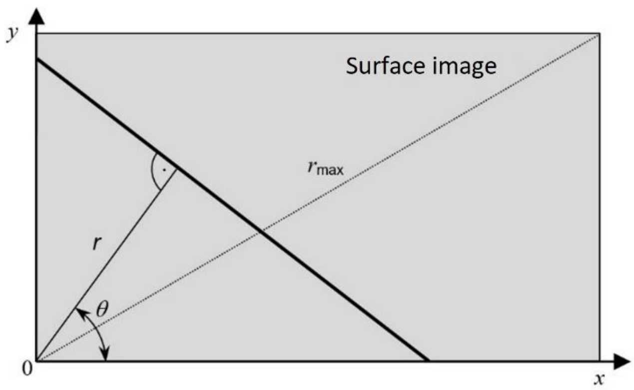


Fig. 2. Straight line in the image and parameters of the normal equation of this line

The mapping of this line, according to the Hough transformation, can be made in the parameter space (*a, b*) or (*r, θ*). The latter variant is more advantageous and used in practice, because the a parameter for lines parallel to the ordinate axes takes infinite values. However, the *r* parameter varies from 0 to r_{max}, and the angle θ can take values from 0 to π.

Another way to identify traces of processing is to use in the surface image processing method the separation of characteristic shapes and other traits describing the traces of processing and the background of the image. This may be needed to evaluate the geometrical parameters of the machining marks [6]. This method is based on the assumption that the surface image is the sum of two signals:

$$o(x, y) = s(x, y) + t(x, y) \tag{3}$$

where: *o(x, y)* – the signal representing the surface image, *s(x, y)* – the signal contained in the surface image, describing the characteristic traces of machining, *t(x, y)* – the signal contained in the surface image, describing all other surface image elements, excluding traces of machining.

This method is not as universal as the methods based on the transformations of Radon and Hough. However, it can be used, for example, to identify traces of abrasive machining on surfaces subjected to selected operations.

The idea of this method, in reference to the identification of straight-line traces of processing, consists in the appropriate suppression of radial components in the Fourier's spectrum of the surface image, and then the separation of components of the Fourier's spectrum describing machining and background traces. This is achieved in a few steps.

The first of these is the Fourier transform of the surface image and the logarithm of the Fourier's spectrum of the surface image. Then the lignite Fourier spectrum is transformed from a Cartesian, rectangular coordinate system into a polar coordinate system. In a polar system, the logarithmized Fourier's spectrum module is defined in coordinates (ρ, φ), where ρ is the length of the initiating property, and φ – the angle defining the direction of the radius of the leader.

In the next step, after multiplying the logarithmized Fourier transform spectrum by the absolute value of the radius ρ, one more Fourier transform is performed, which results in a largely spatial separation of the spectral components of the signals *s(x, y)* and *t(x, y)*. In the spatial frequency plane f_ρ, f_φ the spectral components of the signal *s(x, y)* are centered along the direction of the axis f_ρ, and the components of the background spectrum *t(x, y)* along the axis f_φ. It is thus possible to use in the plane f_ρ, f_φ a programmable attenuation filter suppressing the background components in order to make, in a subsequent step, the separation of the background spectrum components and the spectra of the machining marks. Then, using reverse transformations to those previously described, a picture of machining marks and background is obtained separately.

The presented method of identification of machining marks is presented in detail in [7], and its application to the analysis of traces of machining and defects of sold surfaces is described in [8, 9].

In the Department of Production Engineering of the Koszalin University of Technology, a preliminary version of the computer software called Filter implementing this idea was developed [10]. The next part of the article shows examples of the application of this software for the identification of machining marks on abrasive machined surfaces.

Results of machining marks identification

The Filter program is designed to analyze gray-bit eight-bit images stored in a bitmap format. It allows to separate the background of the image and straight lines contained in the image. The program uses simple (FFT) and reverse (FFT-1) procedures of the fast Fourier transform in the image processing process. The user can determine, from the keyboard level, the degree of amplification of the signal contained in the image and determine the value of the damper filter parameters in the plane f_ρ, f_φ the components of the Fourier image spectrum.

Fig. 3. Results of separation of straight traces of machining and ground surface background

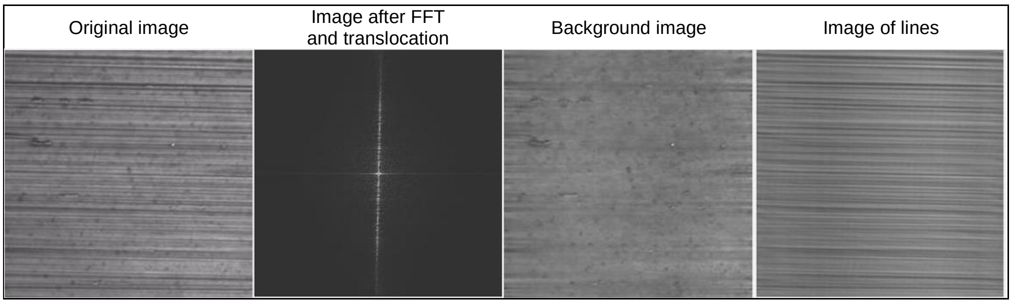


Fig. 4. Separation results of straight-line machining traces and smooth surface background

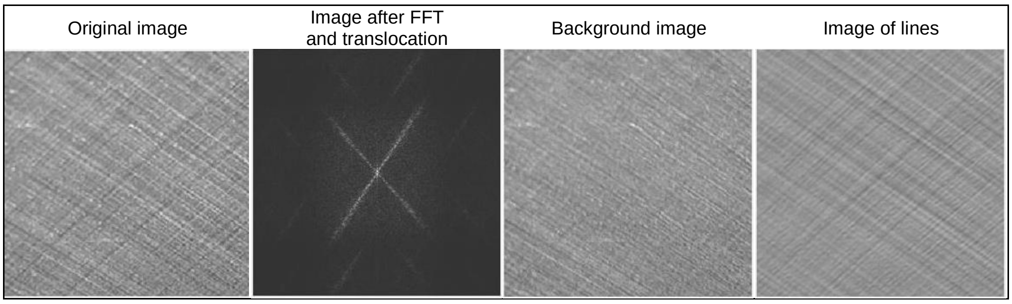
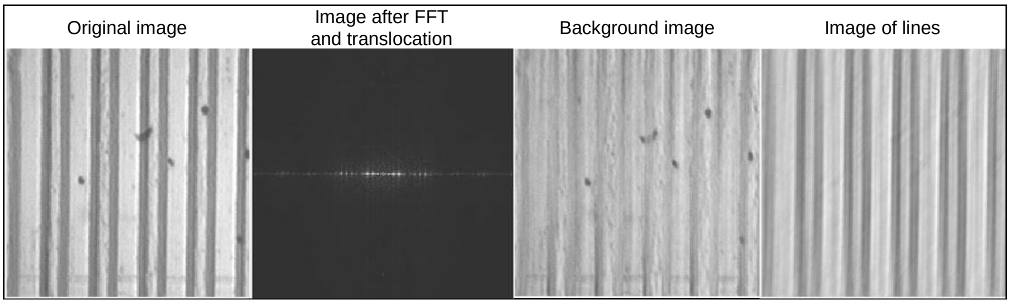


Fig. 5. Results of separation of rectilinear traces and background of the glass surface of a grooved control standard for checking profilometers with lapped groove side surfaces



With the help of the Filtr program, attempts have been made to distinguish characteristic machining marks in the form of straight line sections from images of areas treated with abrasives. Twenty images were studied. They were, among others images of surfaces polished, polished and smoothed.

Four images were obtained: the original, unchanged image area, the image of the Four-dimensional Fourier transform module of the original surface image (obtained as a result of the FFT algorithm), as well as the resulting background images and straight lines.

Fig. 3–5 shows exemplary sets of images obtained during the separation of straight traces of treatment and background of ground, smooth surface and surface of a control pattern with characteristic grooves. In the latter case, the image of groove edges and surface defects visible in the background image were obtained as a result of separation.

Conclusions

It has been shown that the identification of machining marks on abrasive treated areas can be carried out by various methods, including by image processing using integral transformations such as the Radon, Hough and Fourier transformations. In the case of the identification of rectilinear traces of processing, it is possible to use universal algorithms for the filtration of the processed surface image to separate the straight lines contained in the image from the background. Exemplary results of isolation of rectilinear structures obtained during investigations of abrasive surfaces have been presented.

REFERENCES

1. Böhm J.A., Vernes A., Vellekoop M.J. "Investigation of chatter marks on ground surfaces by means of optical methods". *Optics and Lasers in Engineering*. 49, 11 (2011): pp. 1309–1313.
2. Cao F., Lisani J.-L., Morel J.-M., Musé P., Sur F. "A theory of shape identification". *Lecture Notes in Mathematics*. 1948, Berlin, Heidelberg: Springer-Verlag, 2008.
3. Davies E.R. "Object location using the Hough transform". B.G. Batchelor ed. *Machine Vision Handbook*. London, New York: Springer-Verlag, 2012.
4. Mukhopadhyay P., Chaudhuri B.B. "A survey of Hough Transform". *Pattern Recognition.* 48, 3 (2015): pp. 993–1010.
5. Volegov D.B., Gusev V.V., Yurin D.V. "Straight line detection on images via hartley transform. fast hough transform".(ros.). *Proceedings of International Conference Graphicon 2006*, Novosibirsk Akademgorodok, http://www.graphicon.ru/ (22.06.2018).
6. Lawrence D.K., Ramamoorthy B. "An accurate and robust method for the honing angle evaluation of cylinder liner surface using machine vision". *The International Journal of Advanced Manufacturing Technology*. 55, 5–8 (2011): pp. 611–621.
7. Beyerer J., Puente León F. "Adaptive separation of random lines and background". *Optical Engineering*. 37, 10 (1998): pp. 2733–2741.
8. Beyerer J., Krahe D., Puente León F. "Characterization of cylinder bores". E. Mainsah, J.A. Greenwood, D.G. Chetwynd (editors). *Metrology and Properties of Engineering Surfaces*. Dordrecht: Springer-Science + Business Media B.V., 2002.
9. Wang L. "*Image Analysis and Evaluation of Cylinder Bore Surfaces in Micrographs*". Karlsruhe, KIT Scientific Publishing, 2014.
10. Tonderyś M. „Zastosowanie transformacji Fouriera w komputerowej analizie obrazów powierzchni technicznych". Praca magisterska. Wydział Mechaniczny, Politechnika Koszalińska, Koszalin, 2000. ■

Translation of scientific articles, their computer composition and publishing them on the website www.mechanik.media.pl by original articles in Polish is a task financed from the funds of the Ministry of Science and Higher Education designated for dissemination of science.

Ministry of Science and Higher Education
Republic of Poland