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Variability evaluation of signal in two-dimensional wavelet decomposition using fractal dimension

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Abstract

The paper presents the possibilities of using the fractal dimension to evaluate the signals in wavelet decomposition process. The tests have been carried out on samples produced by face milling process for the six types of materials. It has been shown that the fractal dimension enables characterize signal irregularities in quantitatively and qualitatively way.

Keywords: fractal dimension; wavelet transform; geometrical product specifications

1. Introduction

Development of science and technology caused that there is the possibility of in-depth analysis of the phenomena occurring during the production of the machine parts. Measurement and analysis of the geometrical dimensions as well as parameters describing the geometrical structure of the surface of elements produced using by conventional or non-conventional methods [4] is an very important issue [1]. Nowadays, measurements of surface topography are realized through modern measuring systems, which allow a complex analysis of the 3D surface structure [8]. It determines the possibility of adaptation modern algorithms for processing data for geometrical product specifications signals. The signals describing the surface layer of manufactured parts consist of periodic and non-periodic irregularities, therefore, it is important to use of appropriate algorithms for their evaluation. This analysis can

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be performed using the two-dimensional wavelet transform, which was developed at the turn of the twentieth and twenty-first century [7].

The classic methods such as time analysis (time domain), frequency analysis (frequency domain), fast Fourier transform or power spectra density (time-frequency plane) are often replaced by the more efficient algorithms, such as the wavelet transform, which presents the results of analysis in the time-scale plane [2]. This fact is a large advantage because during decomposition of the signal, a changeable size window is used. For the description of the low frequency signal, long sampling intervals are applied, while for the description of the high frequency information, the sampling intervals are much denser [3]. The application of wavelet functions for signal analysis allows to detect the existence of sudden change of signal, as well as to indicate the place of its occurrence [14]. Wavelet decomposition of signals is based on the using of two filters, high pass and low pass. Therefore, at each decomposition level, the input signal is divided into four different signals: horizontal, vertical, diagonal details and the approximation [15]. Thus, it is possible, on particular level of analysis to detect characteristic information, which is not visible at other decomposition level. The information which change rapidly are contained in detail signals, while the low-frequency information are represented by the approximation signal. At subsequent level of decomposition the approximated signal is smoothed [10]. It causes that the signal change own character. Therefore it is important to determine maximum level of decomposition. On this level, the approximated signal and original signal are not differ significantly [6].

In order to evaluate changes in the geometric structure of the surface has been used parameter defining the fractal dimension. It is defined as unit of signal self-similarity, which may be calculated inter alia for three-dimensional surface images. The beginning of the fractal geometry date back to the 60s of the twentieth century and are related with the French mathematician Benoit B. Mandelbrot. At the turn of the years, many researchers applied the fractal geometry, among other to describe the surface topography. It was concluded that the fractal analysis can be used to characterize the surface topography of the samples produced by various methods of manufacturing [12], as well as to predict mechanical and exploitative properties [5]. In particular, the application of fractal dimension to surface produced by machining process can reflect the characteristic properties of the surface, which are impossible to detection using other surface roughness parameters [11]. Adaptation of the fractal dimension to the surface layer analysis allows in a quantitative and qualitative way to characterize surface irregularities [5,13]. For real surfaces, the fractal dimension value is in the range of 2 to 3, wherein for the uncomplicated, smooth surface structure the parameter value is close to 2, while for an surface characterized by a chaotic distribution of the irregularities the value is close to 3 [9]. In this paper authors used fractal dimension which is defined by the formula (1):

$$Sfd = \lim_{\varepsilon \to 0} \frac{\log N(A,\varepsilon)}{\log \frac{1}{\varepsilon}} \tag{1}$$

where: N(A,ϵ) define the minimum number with a radius ϵ> 0, which is required to cover set A.

2. The methodology and results of research

The research was carried out on samples produced by the face milling process for six types of materials. There were chosen four types of steel: 40HM, C45, NC6 and WCL, duralumin PA6 and brass MO58. Machining center AVIA VMC800 was employed to carry out cutting process. The process parameters are shown in Table 1.

Table 1. Process parameters.

Process parameter	sample no. 1	sample no. 2	sample no. 3
f_z mm/tooth	0.02	0.06	0.1
v_c m/min	300	300	300
a_p mm	0.2	0.2	0.2