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Method of controlling cutting tool wear based on signal analysis of acoustic emission for milling

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Abstract

In this paper, a tool wear diagnostic system based on the information contained in the signal of acoustic emission (AE) is considered. In the process, experiments on milling of steel billets 1035 were carried out, with the reference values of cutting force being dynamically monitored with the help of a Kistler 9257B multi-component dynamometer. Registration of the AE signal is performed by an LTR22 modular data acquisition system equipped with an OKTAFON 110 sensor. The method of useful signal filtering from the entire spectrum of AE is carried out using wavelet decomposition. Detection of necessary time periods from the decomposed milling AE signal is suggested for further analysis based on Fourier analysis.

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Keywords: acoustic emission, tool wear, nonstationary system, adaptive system, wavelet transform, CWT;

1. Introduction

Recently, in the light of the development of high-speed machining (HSM) and increasing requirements for precision of machining, the issue of control of tool wear has particular relevance. Existing monitoring techniques can be classified as direct – optical, radioactive, electrical resistivity measurements, and so on – and indirect – parameter measurement of acoustic emission (AE), cutting tool (CT) force, vibration, temperature [1], and so on. Unfortunately, none of these methods are universal due to the complexity of the cutting process.

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Among the contactless methods, AE signal analysis is one of the most effective for the determination of tool wear. The main advantage of AE is that the signal frequency range is much higher than the ambient noise and vibration which are not associated with the cutting process. In early studies, Salgado et al. [3] considered the dependence of acoustic emission signal changes on the feed and torque of the electric motor. Sadettin Orhan et al. [4] showed that the vibration amplitude increases with deterioration of the instrument. Ming-Chyuan et al. [5] and Alonso et al. [6] used the sound of cutting in the frequency range of audibility to control the size of tool wear. Samraj et al. [7] also used the AE while processing in order to predict the tool wear by the dynamic clustering method.

A diagnostic system for turning machining is described by Sidorov [8]. Studies by Sidorov helped to establish that the informative parameter that characterizes CT wear is the dispersion detailing the wavelet coefficients of the AE signal. This parameter is insensitive to changes in processing conditions. It is necessary to mention that for wavelet analysis it is most efficient to use the simplest basis: the Haar wavelet. The minimum duration of the analyzed sample is 0.1 s. Identification of CT wear is carried out by detailing the energy value of the coefficients of the j-th order. For analysis on the Haar wavelet basis it is advisable to take $3 < j < 6$. A schematic diagram of the adaptive monitoring system of CT wear may be implemented in this case as follows (Fig. 1).

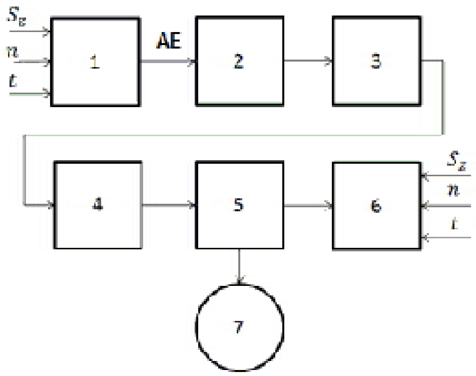

Fig. 1. Principle diagram of diagnostic system of CT wear for turning machining. 1 – Cutting process; 2 – Sensor of AE Signal, 3 – AE signal amplifier, 4 – Wavelet decomposition of four to six levels, 5 – Wear analyzer based on Neural Network(NN); 6 – Wear reference model, 7 – Predicted wear

It should be noted that this scheme will work only for turning in which the AE signal level is conditionally permanent. For milling, where cutting is a periodically repeated process of mill tooth entry, the variable thickness of chip removal and further tooth exit from the billet are the reason why the AE signal in cutting time per tooth will be unstable. This imposes additional restrictions on the method of vibration diagnostics of wear by means of the AE signal spectral analysis. According to Peng et al. [9], the signal to be processed must be linear and constant in time, otherwise the resulting spectrum of the Fourier decomposition of AE will have little physical meaning.

2. Problem statement

The aim of this study is to adapt the CT wear diagnostic system with regard to conditions of milling cutting. The idea of the method is to carry out time sampling (in a dividing on periodically alternating time intervals) of a pre-filtered AE signal, which provides an informative signal consistency within each sampling interval.

3. Experimental part. Testing and measuring equipment

To develop a method for an adequate analysis of the AE signal in the process of cutting, its parameters were compared with reference values of the cutting forces, which were dynamically monitored with the help of a Kistler 9257B piezo-table multi-component dynamometer. Processing of 1035 steel billet with dimensions of 4 × 24 × 40