On-line Monitoring for Cutting Tool Wear Condition Based on the Parameters

Fenghua Han¹*, Feng Xie¹
¹School of Electrical Engineering & Automation, Anhui University, Hefei 230601, China
*E-mail: 1617972207@qq.com

Abstract. In the process of cutting tools, it is very important to monitor the working state of the tools. On the basis of acceleration signal acquisition under the constant speed, time domain and frequency domain analysis of relevant indicators monitor the online of tool wear condition. The analysis results show that the method can effectively judge the tool wear condition in the process of machining. It has certain application value.

1. Introduction
With the wide use of numerical control machine tools, the modern manufacturing system is developing towards the direction of the highly automated. The real-time monitoring for the state of cutting tool is needed. According to the statistics [1], NC machine tools equipped with cutting tool monitoring system can make its productivity increased by ten percent to sixty percent. The utilization rate of machine tools are increased by fifty percent, so the real-time monitoring of machine tool is great significance.

Wang Ming used wavelet theory to extract the vibration signal and analysis the change of the signal amplitude and frequency vibration to determine the state of tool wear. Gao Weijia put forward a kind of method based on artificial neural network after blade abrasion value prediction and used the universal tool microscope to measure the abrasion value.

2. Cutting tool wear monitoring method analysis
The method of cutting tool in machining condition monitoring contains the processing of signal, analyze signal, extract feature and diagnose wear fault. Generally the cutting tool vibration signal contains the valid information of the tool wear. The tool wear state is judged by picking up processing vibration signal from the acceleration sensor and analyzing the relevant indicators[2].

2.1. The time domain analysis
Time domain waveform is usually the most intuitive analysis method. With obvious characteristics of the wear, the time domain waveform directly correspond to different degree of wear. The vibration waveforms show the different shapes[3].

Amplitude parameter analysis of indicators are divided into dimensional parameter and the dimensionless parameter. The dimensional parameters contain the mean, root amplitude, kurtosis, etc. Dimensionless parameters have waveform, pulse, tolerance index and so on. The following is a calculation formula of each index:
Variance \( \sigma^2 = \frac{1}{N} \sum_{i=0}^{N-1} (x_i - \bar{x})^2 \) (1), Kurtosis index \( \chi_q = \frac{1}{N} \sum_{i=0}^{N-1} x_i^4 / \chi_a^2 - 3 \) (2),

Power spectral centroid \( FC = \frac{\sum_{i=1}^{N} f_i p_i}{\sum_{i=1}^{N} p_i} \) (3), The mean square frequency \( MSF = \frac{\sum_{i=1}^{N} f_i^2 p_i}{\sum_{i=1}^{N} p_i} \) (4).

The \( x_i \) for collection of data, \( x_p \) as the peak, \( N \) as the collection data points, \( f_i \) the power spectrum of the frequency, \( p_i \) the power spectrum amplitude.

2.2. The frequency domain analysis

Frequency domain analysis of tool wear monitoring is based on the analysis of time domain waveform. It is to further find out the vibration internal relations of acquisition signal of normal and wear parts.

3. The design for tool wear experiments

The tool wear test is to use new knife from early state to the late continuous processing. In order to study the different levels of wear, the wear mechanism of cutter and the influence law of wear, the different parameters of the time frequency domain are analyzed. The experiment is mainly to collect the acceleration signals under the constant speed. Acceleration sensors are adsorbed to the tool spindle lateral X and Y direction. It will be collected on the stability of the dynamic signal by the acceleration sensors. The signals are transmitted to the acquisition card and imported into the MATLAB software to analyze in the computer [4].

In order to apply vibration test method in tool wear monitoring, as shown in figure 1 is collected vibration signals of tool wear monitoring system.

![Flowchart](image)

**Figure 1.** Collection and analysis of vibration signal monitoring figure.

The system consists of milling drilling machine, the acceleration sensor, a four-channel data acquisition card (NIUSB4431) and PC software MATLAB analyzer. The experiment of specific machine of ZXJ7016 is the speed regulating pole change motor machine. The cutter material is a straight shank end mill with two teeth. The sampling frequency is 20000 Hz. The sampling time is 2 seconds and the signal acquisition is taken from the new state to severe wear.

4. Results of data analysis

The spindle speed of 750 r/min, feeding rate of 70 mm/min, turning quantity is 0.5 mm and the processing thickness is 5 mm.

To contrast the different level tool wear state are based on the analysis of the time domain and frequency domain parameters. The different parameters have different sensitive of the wear degree. It is need to select a number of effective parameters as the characteristics of fault diagnosis [5].
From figure 2 to figure 5 in the line chart, the average, kurtosis, impulsion index and tolerance index is more sensitive indicator of tool wear signals. These can be used as mixed characteristics of tool wear monitoring.

The above two line chart about the frequency domain index, both the mean square frequency and the power spectral centroid are sensitive to the vibration signal of the tool wear and have better signal indication. Here are all wear period of time domain and frequency domain spectrum analysis[6].
The vibration signal can get varying degrees of cutting tool wear from the time domain and frequency domain. Above a few of frequency domain diagrams are typical. Due to the spindle speed switch frequency is 12.5 Hz, the experiment of the cutter material has two teeth and the switch frequency is 25 Hz. It can be seen the frequency of 125 Hz or 200 Hz and 550 Hz, in the early or mid time of the tool wear degree difference is not big, but have great peak. Contrasting with the wear of late, the frequency of the tool’s wear is not as high as the frequency of 25 Hz or more than the set value, that’s said the tool wear badly. These as shown in figure 8 ~ 13 stages time frequency domain[7].
5. Conclusion
Through the analysis of the relevant, the vibration signal can be observed from the time domain and frequency domain in the figure. In the early or middle time of the tool wear degree, the difference is not big, but the middle is relatively stable. The late vibration is more intense. According to the different vibration signal, the cutting tool indicates different wear state[8]. In the time domain parameters, the mean square amplitude, waveform of index and kurtosis distinguish from the cutting tool wear state. In the frequency domain parameters, the mean square frequency and power spectrum centroid of the cutting tool wear have obvious corresponding characteristic. The example proves that the time domain and frequency domain analysis method can effectively extract the characteristics of the cutting tool and identify the quality problems of the cutting tool wear. To a certain extent, the method improves the accuracy of tool wear monitoring in real time.

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