Cutting tool wear analysis using sound signal and simple microphone

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Abstract. Cutting tool is an important part of machining processes which in the operation frequently runs into wear. The wear cutting tool produces an imprecise product with low quality surface, may endanger machine tools by stimulating chatter. In this study, low cost and fast analysis of the wear of cutting tools in turning and drilling processes are proposed. For that purpose, the experimental set-up which consists of operating turning and drilling machine, simple microphone and Personal Computer (PC) with a sound card are set out. The wear of cutting tools are made by applying artificial wear. The sound data from normal and wear cutting tools of operating turning and drilling machines are recorded by using simple microphone and PC with a sound card. The obtained sound signals are then analyzed in the form of time and frequency domain, spectrogram by Wavelet Transform (WT). It is found that sound signals in time and frequency domain have a significant rise of amplitudes in wear conditions. The spectrograms exhibit the special contours which sign the existence of wear. The results demonstrate that the proposed method can analyze the cutting tool wear very well.

1. Introduction

Condition monitoring plays an important role to make sure that structures and working machines run the function as they should be. By this reason, condition monitoring has become an important subject in the area of engineering. Several methods have been studied to get the most effective way of monitoring the condition of structures [1-4] and the working machine [5-7]. One of the important things that need to be monitored in industries is the machining process, where the product precision is really affected by the condition of the cutting tool.

Cutting tool is an essential part of machining processes which in its operation frequently runs into wear. The wearing tool produces imprecise product with low quality surface and may endanger tool machine by stimulating chatter. Several methods have been investigated to analyze and to detect tool wear [8-10]. A variety of sensors was used to capture the necessary information on the machining process, such as load cells, accelerometers, and acoustic emission (AE) sensors. It was found that AE sensors have more advantages [11,12]. Moreover, different tool wear cases could be detected by applying the sensing principle of AE signals [13]. The researcher needs to spend more expenses on the standard experiment microphone.
In this study, the sound signal and simple microphone are proposed to get sound signal data for the analysis of the weariness of cutting tools in the turning and drilling process. The simple microphone which is connected to sound card and personal computer is used as a sensor to grab the sound signal from the turning and drilling process. The sound signals are then analyzed by using Fast Fourier Transform (FFT) and Wavelet Transform (WT). From this research, it is hoped that the potency of simple microphone and soundcard to analyze and detect cutting tools in turning and drilling processes can be shown as one of the solutions to get a low-cost instrument for cutting tool wear analysis and detection.

2. Methods

In order to check the ability of the proposed method, the experimental set-up which consists of operating turning and drilling machine, simple microphone and personal computer (PC) with a sound card are set out. The experimental set-up for the turning process and drilling process can be seen in Figure 1 and Figure 2, respectively. The microphone in this setup is Krezt K-818 with a frequency range of 30Hz to 18 KHz, and the sensitivity of -32dB 3dB, which usually used as a part of the sound system.

![Figure 1. Experimental setup for turning process.](image1)

![Figure 2. Experimental setup for the drilling process.](image2)
Before conducting the experiment for normal and wear conditions, the sound signals of the environment with operating machines are grabbed by ten times averaging. This signal will be the basic of filtering for any condition of operation (normal or wear). The sound signals that will be analyzed are the grabbed sound signal minus the sound signal of the environment. So, the analyzed signal is clear from the noise of the environment. The sound data from normal and wear cutting tools of operating turning and drilling machines are recorded by using a simple microphone and PC with the sound card and then filtered. The wear of cutting tools is made by applying artificial wears. The obtained sound signals are then analyzed in the form of time and frequency domain, spectrogram by Wavelet Transform (WT). Both conditions data are then compared to get the characteristic of the sound signal in wear condition.

3. Results and discussion
In this work, the sound signals of turning and drilling processes in normal and wear cutting tool condition that has been filtered by the environmental sound data are proceed in advance by using FFT and WT. The output will be frequency domain signal and scalogram in the range of 0 – 100 Hz.

3.1. Turning process
Figure 2 to Figure 6 show the comparisons between normal and wear condition with the operation condition of 1000 rpm spindle rotation, 0.05 mm/rev feeding, and 0.5 mm depth of cut. The comparisons of data are presented in the form of the frequency domain and scalogram of wavelet transformation. The level of wear is 0.3 mm, 0.4 mm and 0.8 mm, and the level named wear 1, 2, and 3, respectively.

![Figure 3](image1.png)
*Figure 3.* The sound signal data of turning in normal condition; (a) frequency domain, (b) scalogram.

![Figure 4](image2.png)
*Figure 4.* The sound signal data of turning in wear condition 1; (a) frequency domain, (b) scalogram.
In normal conditions, because the signal of the environment is removed, the frequencies with high amplitudes are not found in the range of 0 to 100 Hz. In early condition of wear, a high magnitude in the frequency of 53 Hz appears and raises when the wear level is added. The frequency of 53 Hz is almost the same with 3 x rpm, which may exist by the change of force on the tool caused by wear. In the scalogram, it can be seen that the dramatically contour changes happened by the wear escalation. The scalograms for wear conditions 1-3 show the significant contour changes when the level of wear increased.

3.2. Drilling process
The comparison between normal and wear conditions with the operation condition of 635 rpm spindle rotation, 0.18 mm/r feeding are shown in figure 7 to figure 9. The comparisons of data are presented in the frequency domain and scalogram of wavelet transformation. The level of wear is about 0.3 mm, and 0.8 mm, and the level named wear 1, and wear 2, respectively.
Figure 7. The sound signal data of drilling in normal condition; (a) frequency domain, (b) scalogram.

Figure 8. The sound signal data of drilling in wear condition 1; (a) frequency domain, (b) scalogram.

Figure 9. The sound signal data of drilling in wear condition 2; (a) frequency domain, (b) scalogram.
In the frequency domain signal, it can be seen that there is no high amplitude in the range 0 to 100 Hz, but in the early condition of wear, some frequencies start to have higher magnitude, and this condition keep raises up when the wear level are added. In the scalogram, it is shown that the dramatically contour changes occurred by the wear escalation. In the highest level of wear 0.8 mm, one dominant frequency (47 Hz) appears with high amplitude. The frequency of 47 Hz is almost the same with 4 x rpm, which may exist by the change of force on tool caused by wear. This frequency still needs to be investigated, but at least the result shows higher amplitude by the increasing of wear level.

4. Conclusions
From the analysis that has been conducted for cutting tool wear in turning and drilling process using sound signal and simple microphone, it is shown that the proposed method can detect the cutting tool wear very well. The FFT and WT were applied successfully as the sound signal processor. The signatures of wear are explored by using the frequency domain signal and scalogram. It can be concluded that a simple microphone can be used as the alternative of a sensor to detect and analyze the cutting tool wear in turning and drilling process by the sound signal base method. The data grabbed by a simple microphone and sound card determined the real condition of turning and drilling tool conditions.

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