ABSTRACT OF DISSERTATION

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Vibration analysis in machining of thin-walled workpieces using Hilbert-Huang Transform

（Hilbert-Huang Transform による薄肉加工物の機械加工における振動の解析）

Thin-walled mechanical parts are widely used in industries in order to develop the light-weight structure of machine such as turbine blade, impeller, and aerospace frame. And they are often processed by machining operation, such as turning and milling. However, machining of these mechanical parts are more challenging than rigid ones. The main reason of this is that the dynamic properties, such as stiffness and damping, are very low. Therefore, machining of thin-walled mechanical parts can induce chatter vibration, accelerate tool wear, and lead machining error easily which are major obstacles in order to achieve desired products.

In machining process, those negative phenomena are often monitored by analysis of vibration, cutting force, and temperature which are often measured by such kinds of sensors. The advanced sensors would exert their potential with an appropriate signal processing technique to extract the features of measured signals which provide an important information about machining states. Another word, signal processing is important to guarantee reliable results.

In vibration analysis, researchers use many kinds of signal processing techniques for machining process monitoring. Fast Fourier transform (FFT) is commonly used for vibration analysis in frequency domain to detect chatter and tool wear in turning and milling. Vibration analysis method in energy-time-frequency domain is also used for machining process monitoring. The time-frequency analysis (TFA) includes short time Fourier (STFT) and wavelet transforms. However, they are not suitable for analyzing of nonlinear and non-stationary vibration signals just like signal obtained in machining processes.

A recent TFA method which deals with nonlinear and non-stationary signals is Hilbert-Huang transform (HHT). HHT is applied for detecting fault in mechanical transmission, such as gear and rotating machinery. However, the use of HHT to analyze signal in turning and milling is limited. Therefore, HHT is applied in this study for machining process monitoring by means analyzing vibrations obtained in machining. In this study, machining process monitoring is including chatter detection, sudden change of machining stability caused by lubrication, sudden change of machining stability caused by obstacle in machining, and tool condition monitoring. In order to achieve the goals of this research, extensive experiments were conducted under various cutting conditions. Signals obtained in machining tests were analyzed by FFT, STFT, and HHT.

The results showed that the empirical mode decomposition (EMD) decomposed complex vibration into simple components, and each one of them contained a unique vibration mode caused in machining. EMD can sift out the signal containing chatter frequency from others. In chatter detection in milling based on HHT spectrum, the energy in stable milling was concentrated in particular frequency. Besides, the energy in unstable milling (occurring chatter) was chaotic and the frequency was not constant.

And, the HHT can reveal the difference excitation among cutting edges. HHT can reveal the effect of cutting fluid on the stability of milling which was pointed out in Hilbert spectrum. In Hilbert spectrum, the energy appeared in certain frequency range for dry cutting, and energy vanished when tool entered in the wet area. Besides, the energy in Hilbert spectrum displayed a chaotic spectrum when milling was unstable caused by obstacle. And, Hilbert spectrum of the stable milling showed that the energy was distributed in particular frequency. HHT can be utilized for tool condition monitoring. Based on the Hilbert spectrum, milling using worn and chipped tools can be distinguished from milling using normal tool. FFT was not suitable for analyzing stationary vibration signal which frequency changes over cutting periode. STFT spectra gave blurry and blocked spectra because of its time-frequency resolution. Besides, HHT spectra showed a significant improvement of time-frequency resolution making the frequency components easier to be identified.

Key words: machining process monitoring, Hilbert-Huang transform, chatter vibration, sudden change of machining stability, tool condition monitoring.