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Application in testing courses of milling force signal processing

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Abstract: The course of testing technology plays an extremely important role in the informatization of machinery manufacturing industry and the cultivation of innovative talents. In order to better let students to grasp the sensor output signal how to obtain clean signal through signal processing, this paper puts forward the cutting force signal processing case in milling experiment, help students to combine theory with practice.

1. Introduction

With the rapid development of advanced manufacturing industry, there is an urgent need for a large number of high-quality talents with solid basic theory and professional skills in manufacturing industry, which puts forward new requirements for modern engineering education. It is an effective way for schools to cultivate high-quality and skilled personnel by means of school-enterprise cooperative personnel training [1-2]. The basic course of mechanical testing technology, as a basic course of mechanical specialty, plays a very important role in product development, manufacturing, quality control and performance experiment. The function of signal conditioning is to adjust the amplitude, transform the form and suppress the noise of the electrical signal output by the sensor, so as to facilitate the transmission and analysis of the signal, and play an important role in the correct collection and measurement of the signal [3-4]. It is difficult for students to grasp and understand this part of content. Only by combining theoretical analysis with practice promotes students fully to grasp signal processing methods. Therefore, this paper proposes the case study of milling force signals processing in milling experiments to strengthen students' grasp of signal processing knowledge.

2. Milling force signal processing in milling experiment

2.1 Test system and signal acquisition

Milling process is a common machining method, by rotating the tool on the surface of the workpiece cutting material. Milling process is a kind of high precision, high efficiency, high adaptability, high flexibility of processing. Cutting force is one of the important machining parameters in milling process. The measurement of cutting force can provide the following information:

a. Tool state evaluation: The size and change of cutting force can reflect the state of tool wear and fracture. By monitoring cutting force, the condition of the tool can be evaluated in time to ensure the quality and safety of processing.

b. Processing state monitoring: The size and change of cutting force can reflect the processing state, such as cutting vibration and tool load. By monitoring the cutting force, it can find the abnormal machining state in time, adjust the machining parameters and ensure the machining quality.

c. Tool life prediction: The size and change of cutting force can reflect the trend of tool wear and fracture. By monitoring cutting force, the life of the tool can be predicted and timely replacement can be carried out to avoid the risk of machining quality decline and tool fracture.

d. Optimization of machining parameters: The size and change of cutting force can also reflect the rationality of machining parameters, such as cutting speed, feed speed and cutting depth. The machining parameters can be optimized and the machining efficiency and quality can be improved.

Cutting force measurement is very necessary in milling process. It can provide key machining information and parameters to ensure machining quality and efficiency. Therefore, it is necessary to select a suitable cutting force sensor and build a test system.

A test system is usually composed of test objects, test instruments, measuring equipment, control equipment, data processing equipment and test environment, through which the test objects are tested and analyzed. Figure 1 is sensor installation in a simple milling experimental, and Figure 2 is a schematic diagram of the testing system.

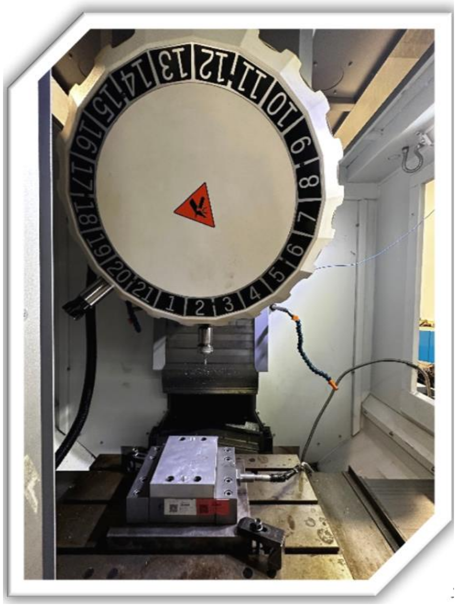


Figure 1 Sensor installation in experiment

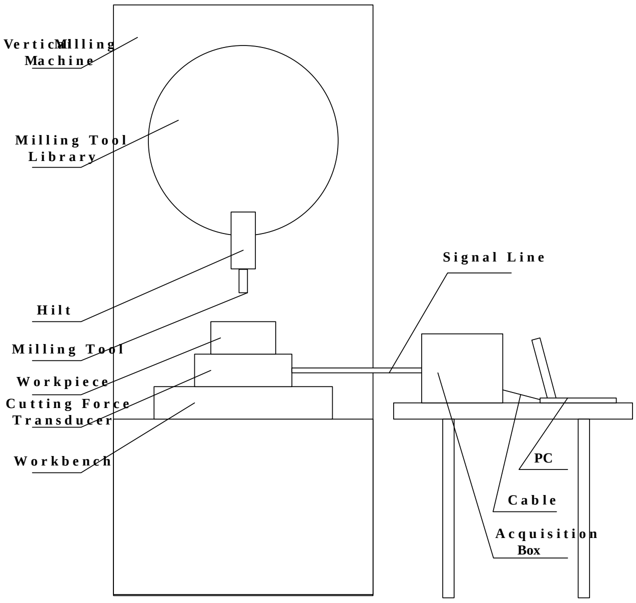


Figure 2 The schematic diagram of the testing system

As shown in Figure 2, a cutting force sensor is arranged and fixed below the workpiece above the workbench. The milling force in X, Y and Z directions can be measured. After the measured data of the cutting force sensor, it is transmitted to the acquisition chassis through data lines through signal amplification, filtering and A/D conversion. The computer gets the value information by processing and analyzing the input signal.

2.2 Processing and analysis of milling force signal

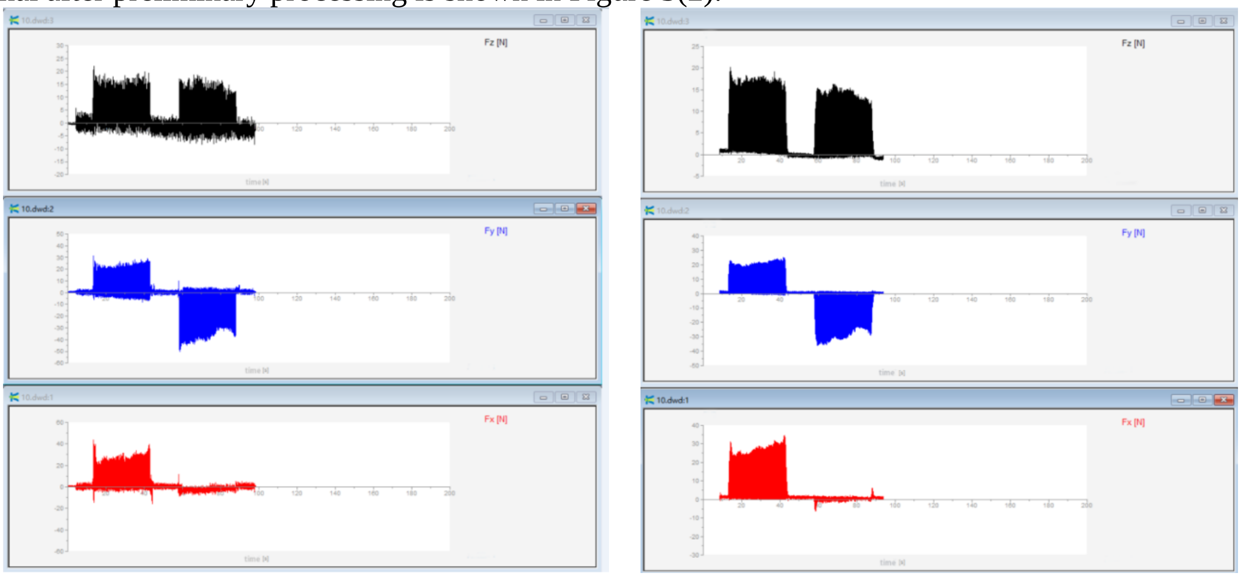
In the process of signal sampling, an appropriate sampling frequency should be selected to accurately restore the original signal. Generally speaking, the sampling frequency should meet the requirements shown in Formula (1).

$$f_s \geq 2 * f_{max} \tag{1}$$

Specifically, if the highest frequency of a signal is f_{max}, then the sampling frequency f_s must be greater than or equal to twice f_{max}. This means that when sampling, the sampling frequency should be high enough, at least twice the highest frequency of the signal, to fully retain the frequency information of the signal, which is the **sampling theorem**. When sampling theorem is applied, the sampling frequency should be selected according to the highest frequency of the signal. If the sampling frequency is less than twice of the maximum frequency of the signal, under sampling will occur, resulting in aliasing phenomenon in the sampled signal, which makes it impossible to accurately restore the original signal.

In practice, a higher sampling frequency is usually selected to ensure that the signal will not be aliased in the sampling process and to retain sufficient frequency information for satisfying the sampling theorem. Fig. 3(1) shows the original data of F_x, F_y and F_z of the same set of milling parameters, which were used for up-milling and up-milling respectively. The maximum frequency f_{max} was 1100HZ, so 2500HZ was selected as the sampling frequency f_s of the sensor.

Firstly, the original signal of cutting force is processed preliminarily, that is, the signal drift compensation and smoothing processing are carried out. The signal drift compensation refers to the correction of the signal to eliminate the drift caused by the signal during the long running process. These drifts may be caused by changes in ambient temperature, aging of components, loosening of machines and other factors. In signal processing, smoothing is a common signal processing method, also known as filtering or denoising. The purpose of smoothing is to eliminate noise or jitter in the signal, so that the signal becomes more stable and stable. Due to the large amount of data, the smoothing method of moving average is adopted, and 15 numbers of window size are selected, that is, the average value is taken every 15 points during the sliding average processing. The original signal after preliminary processing is shown in Figure 3(2).



(a) Raw signal not processed (b) Initial processing of the original signal

Figure 3 Cutting force raw signal

Next, the cutting force is further processed, and a small section of the signal is intercepted smoothly in the original signal, and 10000 points are intercepted for 4 seconds. Milling force signals in three directions are used to synthesize milling force resultant signals, as shown in Formula (2). The milling force resultant signals are denoised by using the smoothing method of moving average and 15 numbers of window sizes are selected, that is, average values are taken every 15 points in the sliding average processing process, and initial denoising is done on the signals, and then low-pass filter is used for secondary denoising. As shown in Figure 4.

$$F = \sqrt{F_x^2 + F_y^2 + F_z^2} \tag{2}$$

In order to facilitate subsequent analysis, it is necessary to convert the time-domain signal into the frequency-domain signal, which can be carried out using Fourier transform (FT). However, since the cutting force signal collected by the cutting force sensor is discrete, discrete Fourier transform (DFT) should be used, as shown in Equation (3).

$$x_k = \sum_{n=0}^{N-1} x_n e^{-\frac{2\pi i}{N}kn} \tag{3}$$

Where x_n is the time-domain discrete signal, x_k is the frequence-domain discrete signal, N is the number of sampling points of the signal, and i is the imaginary number unit.

However, the time-frequency domain conversion method commonly used for discrete signals at present is fast Fourier transform (FFT). FFT is a fast algorithm to calculate discrete Fourier transform, which is still a discrete Fourier transform in essence. There are many ways to implement FFT algorithm, common including butterfly operation, divide and conquer method. FFT was performed on the above secondary processed cutting force original signal, and the results were shown in Figure 5.

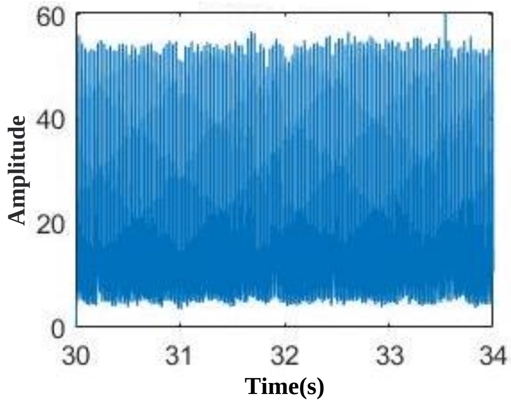


Figure 4 The original signal after secondary processing

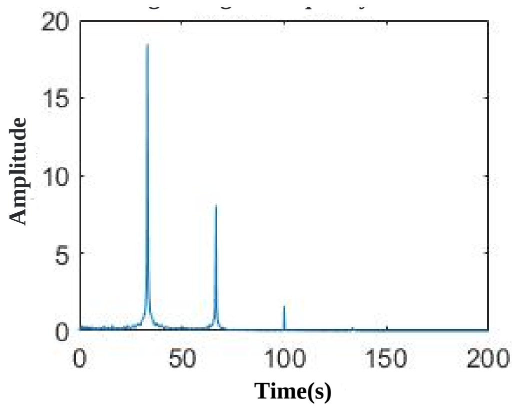


Figure 5 Frequency domain diagram after FFT

In the actual milling process, the existence of frequency doubling is very important for the analysis and control of cutting force. Frequency doubling can be used to determine the relationship between spindle speed and cutting force, so as to help optimize cutting parameters and improve machining results. At the same time, frequency doubling can also be used to detect abnormal conditions in the cutting process, such as tool wear, material deformation and other problems. Therefore, frequency doubling is a very important reference in the analysis and control of milling force signals. Through the analysis of frequency doubling, the precision and efficiency of milling can be improved effectively.

To sum up, the cutting force signal is an important parameter in the milling process, which can reflect the cutting state and the cutting characteristics of the workpiece material in the machining process. The cutting force signal can be obtained by the cutting force sensor in real time, which can be processed and analyzed, and the information about cutting state and machining quality can be obtained. The process of signal processing and analysis includes filtering, FFT transformation, time domain and frequency domain analysis, peak extraction, drift compensation and other steps. These steps can help us extract useful information from the signal, such as the size of the cutting force, frequency and waveform. This information can help us optimize machining parameters, predict workpiece quality, diagnose tool wear, etc., and improve the efficiency and quality of milling.

3. Conclusion

This paper presents the application in testing courses of milling force signal processing. It assists to strengthen students' grasp of signal processing knowledge, such as sampling theorem, time domain analysis and frequency analysis.

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