A study on dynamic signal processing and analysis to monitor positioning system with ball screw

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Nowadays manufacturing industry responds rapidly and flexibly to the various demands of products. And it is changing by the uncertainty and variety of performance required in the factory floor because the production system is becoming intelligent, automatic and combined. With the trend of factory automation, especially, manufacturing equipment tends to be put into 24-hours operation a day. However, these trends in manufacturing equipments also increase the possibility of various mechanical problems and require high maintenance cost. Therefore, it is necessary to develop the condition-based monitoring (CBM) and diagnosis, which maintain the best performance of manufacturing machinery without errors. According to expansion of high precise equipments markets, recently the role and demand of positioning system is also increasing. In this paper, we design a CBM system to monitor condition of a ball screw (BS) type positioning system. Generally, to evaluate the operating conditions of the equipment in the industrial field, various physical properties are monitored. Among them, vibration and Noise signals are the most important indicator and it is effectively used in many diagnosis systems for equipment. So, we measure vibration of the BS type positioning system as an indicator of operation condition. And then the signals are analyzed on the frequency domain by using the Fast Fourier Transform (FFT) method to evaluate dynamic characteristics of the BS type positioning system.

1. Introduction

Recently, along with the intense competition to increase productivity, interest in the diagnosis of manufacturing equipment is rising to reduce maintenance costs and increase efficiencies of plants. Also, because the manufacturing equipment becomes intelligent, automatic and combined, the economic losses caused by the equipment failures are increasing. Maintenance based on condition based monitoring (CBM) is to perform maintenance considering indicators show that equipment is going to fail or that equipment performance is deteriorating. For the maintenance based on CBM, it is necessary to correctly evaluate the condition of equipment from the indicator signals. The maintenance is effective not only to improve safety and but also to increase productivity.**[1]** Especially, the rate of operation is increased by eliminating unnecessary regular maintenances. When failure occurs, the lead time is reduced by finding the cause of failure promptly. Also, through continuous condition monitoring, maintenance based on CBM has an advantage in the economical aspect by avoiding the overstock of essential and expensive components in the production line.

For a long time the studies on condition monitoring have been conducted. Particularly, in order to monitor a condition of the rotating machinery, numerous theories and methods have been studied. **[2]** But the studies on the reciprocating equipments like a linear positioning system do not have made achievements because the signals from the equipment are changing every time when they are measured. It requires advanced signal measurement, processing and analysis.

In order to research signal measurement and processing methods of linearly reciprocating machinery, in this study, we design a CBM system to monitor signatures of a ball screw (BS) type positioning system. And then we measure vibration of the BS type positioning system as a indicator of operating conditions. Finally, the signals are analyzed in the frequency domain by using the Fast Fourier Transform (FFT) to evaluate dynamic characteristics of the BS type positioning system.

Fig. 1 Ball screw type positioning system and condition based monitoring system

Equipment	Specifications	Value	Model (Maker)
Accelerometer	Frequency range	0.5~5000 Hz	356A16 (PCB PIEZOTRONICS)
	Voltage sensitivity	100 mV/g	
A/D converter	Resolution	24 bits	PXI-4472 (NATIONAL INSTRUMENTS)
	Sampling Rate	102.4 kS/sec	
	Input Range	-10 ~ +10 V	
Signal Analyzer			PXI-8187 (NATIONAL INSTRUMENTS)

Table 1 Specifications of monitoring system

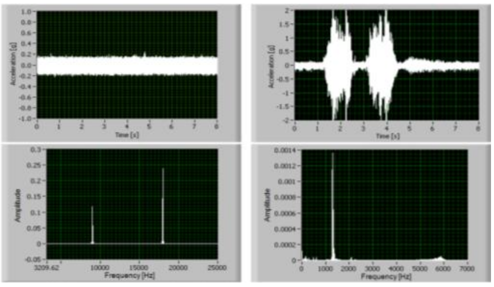

Fig. 2 Time and frequency domain signal analysis when the positioning system is stationary (Left) and is operated (Right).

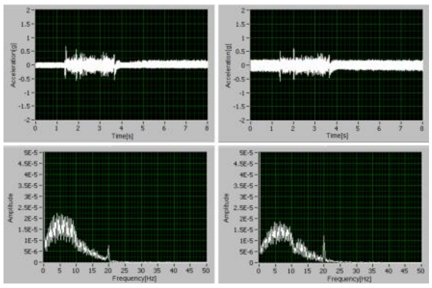

Fig. 3 Time and frequency domain signal analysis when the positioning system is operated with 20 N (Left) and 40 N (Right).

2. Experiment setup and method

In order to measure and analyze vibration signals of the BS type positioning system, a monitoring system as shown in Fig. 1 is designed. Specifications of monitoring system are listed in Table 1. An accelerometer is centrally located at a stage of BS type positioning system to measure z-directional vibration. When the positioning system is stationary or operated, the vibration signal is measured. A stage of the positioning system travel 38.2 mm back and forward for 5.6 seconds. The velocity and acceleration are 13.4 mm/sec and 500 mm/sec^2 respectively. The signal processing is based on the Fast Fourier Transform (FFT) by using the LabVIEW software. The Hanning window function is used for FFT. Additionally, experiments are conducted with intentional loads against a moving direction because we measure signals made by increasing a friction between the screw and the stage.

3. Results

The stationary frequency components of the vibration are 120 Hz, 240 Hz, 360 Hz, 9,000 Hz and 18,000 Hz as shown in Fig. 2 (Left). When the positioning system is operated, the frequency component of 1,300 Hz additionally occurs as shown in Fig. 2 (Right). Also, when intentional additional loads are engaged, the frequency component of 20 Hz increases and the frequency components which are lower than 20 Hz are shifted to high frequency.

4. Conclusions

In this paper, vibration of BS type positioning system is analyzed by using FFT. The stationary frequency components of 120 Hz, 240 Hz and 360 Hz are harmonics from a power source of 60 Hz. And the frequency components of 9,000 Hz and 18,000 Hz are harmonics made by a pulse width modulation (PWM) control signal of 900 Hz. The operation frequency component of 1,300 Hz is a transient response. This transient response requires an analysis based on the mathematic model and time frequency domain; so we plan to investigate this in future work. In the further experiment with intentional loads, we know that a friction load made by performance degradation of equipment increases the frequency component of 20 Hz. It is an increase of electrical operation source and can be used as an indicator to evaluate a performance of equipment.

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