TUPA06

STUDY THE ACTIVE VIBRATION CONTROL SYSTEM OF THE PARALLEL 6-DOF PLATFORM

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Abstract

With the development of high-energy synchrotron radiation light source with high energy, high brightness, low emittance and nano-scale light spot, accelerators and beamline stations have higher requirements for the stability of the system, and active vibration isolation technology has been paid more and more attention. It has become the key technology for the development of major scientific devices (such as high-energy synchrotron radiation light source, free electron laser, etc.) in the future. In this paper, an active vibration control system driven by piezoelectric ceramic actuator with strong adaptability is designed. NI Compact-RIO real-time control system and Fx-LMS adaptive filter control algorithm are used for the active vibration control system. The identification method of input and output channels and the active control module are simulated by MATLAB. And an active vibration control system based on a parallel 6-DOF platform was built for experimental verification. The experimental results show that the designed active vibration control system has a good control effect for low-frequency micro-vibration

THE ACTIVE CONTROL PRINCIPLE OF MICRO-VIBRATION

In the face of the situation that the characteristics of these systems are unknown or often changing and can't be completely determined in advance, how to design a satisfactory control system that can actively adapt to the unknown or changing characteristics is the problem to be solved by the adaptive control algorithm. And this paper taken the FX-LMS algorithm as one control core of the system, and the principle were shown as figure 1.

In practical application, the error signal (vibration response signal) $e(n)$ is not a simple superposition of the filter output $y(n)$ and the desired signal $d(n)$. There is a transfer function of a secondary channel between $y(n)$ and $e(n)$. $\boldsymbol{S}(z)$ is the transfer function from the control input of the actuator to the load response, which represents the dynamic characteristic of the actuator. In physics, the secondary channel $\boldsymbol{S}(z)$ includes D/A, power amplifier, active actuator, controlled system, error sensor and A/D, etc. The whole filtered Fx-LMS algorithm can be simply summarized as follows:

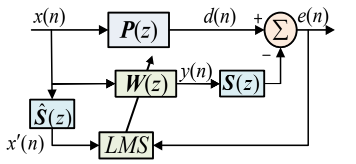

Figure 1: The Principle of FX-LMS algorithm.

$$\begin{cases} y(n)=\sum_{l=0}^{L-1} w_l x(n-l) \\ e(n)=d(n)-S^T Y(n) \\ w(n+1)=w(n)+\dfrac{\tilde{\mu} e(n) X'(n)}{\gamma+X'^T(n) X'(n)} \\ X'(n)=\left[x'(n) \quad x'(n-1) \quad \cdots \quad x'(n-L+1)\right] \\ x'(n)=\sum_{h=0}^{H-1} s_h x(n-h) \end{cases}$$

SIMULATION OF THE SECONDARY CHANNEL IDENTIFICATION ALGORITHM

This paper assumes that the channel model to be identified is $\boldsymbol{S}(z)$ = [0.038,0.0875, -0.175, 0.035, -0.175, 0.0875, 0.21, 0.0385, 0.084, -0.105]. The excitation signal $x(n)$ is taken as the order of Gaussian white noise. Through MATLAB simulation, the secondary channel model parameters of the system can be effectively identified by using Fx-LMS adaptive algorithm.

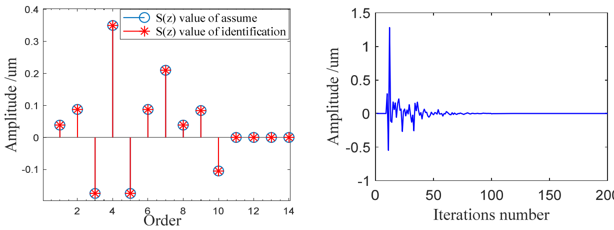

Figure 2: The secondary channel identification results(left) and the error of the simulation(right) in the identification process.

SIMULATION OF ACTIVE VIBRATION CONTROL ALGORITHM

In this paper, the MATLAB is used to simulate and verify the algorithm of the active vibration control module. The excitation source set here is a square sinusoidal wave with amplitude of 2mm at 5Hz, 15Hz and 20Hz, and the multi-frequency interference signal with white Gaussian noise of 0.1um is superimposed. By calculation, the maximum amplitude of the system is 4.96um without active vibration control, and when there is a vibration control force, the maximum amplitude of the system is 0.15um. The system has a good isolation effect in theory.

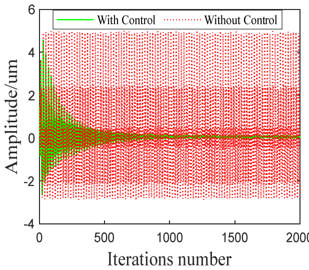

Figure 3: Simulation of active vibration control.

DESIGN OF ACTIVE VIBRATION CONTROL SYSTEM

The control process of the active vibration control system designed in this paper mainly includes two parts: the secondary channel identification process and the active vibration control process. The control signal communication and process data transmission are realized through the FIFO data transmission module between the host computer and the target computer. The whole control process is shown in Figure 4, and the software architecture of system is shown in Figure 5.

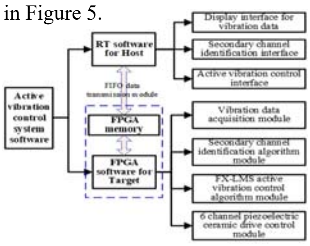

Figure 5: Software architecture of the active vibration control system.

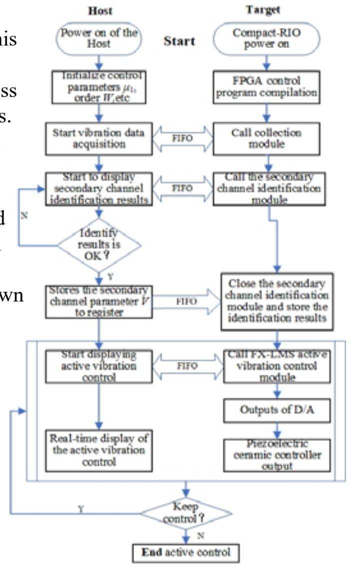

Figure 4: Flow block of the active control system.

EXPERIMENTAL STUDY ON ACTIVE VIBRATION CONTROL

This paper presents a single direction active vibration control system based on a parallel 6-DOF platform, which is mainly used to control the low frequency micro-vibration in the vertical Z direction of the platform.

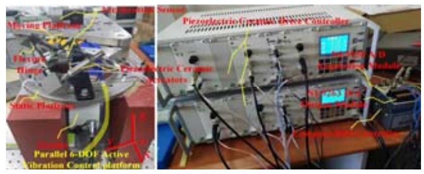

Figure 6: The active vibration control system base on parallel 6-DOF platform.

In the secondary channel Parameter identification experiment, which was used to identify the secondary channel parameters of the Z direction of the parallel platform.

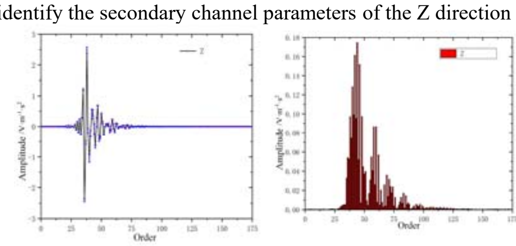

Figure 6: Secondary channel identification result of the 6-DOF platform(left) and the Standard deviation distribution of the results. (right).

In this paper, different frequency excitation and vibration control experiments on the vertical Z direction of the platform are carried out to test the low frequency damping effect of the control system. The vibration damping effect under different excitation frequencies is listed in Table 1. And figure 7 shows the experimental results of vibration exciter at 7Hz.

Table 1: The Vibration Reduction Results Under Different Frequency Exciting Conditions

Exciting frequency /Hz	With control /μm	Without control /μm	Vibration reduction rate /%	Vibration attenuation /dB
7	9.179	2.247	75.52	14.66
10	9.475	1.017	89.27	23.89
15	9.955	0.512	94.85	52.04
20	9.634	0.554	94.24	43.41
25	7.234	0.412	94.31	70.21
30	6.165	0.561	90.91	58.16
40	4.924	0.943	80.84	64.23
50	4.493	0.834	81.43	71.82

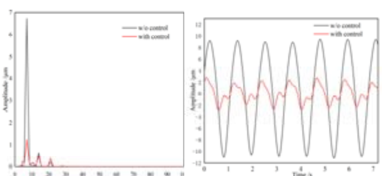

Figure 7: Experimental results of active vibration control

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