무선 센서 인터페이스를 이용한 능동 준영강성 제진기

Active QZS isolator using wireless sensor interface

*팜반트룽 [1], #안형준 [2], 김영한 [3], 최동수 [4], 손기동 [5]

*Pham Van Trung[1], # Hyeong-Joon Ahn (ahj123.ac.kr)[2], Younghan Kim[3], Dongsoo Choi [4], Kidong Son[5]

[1]숭실대학교 기계공학과, [2]숭실대학교 기계공학과, [3]숭실대학교 정보통신전자공학부, [4]져스텍 기술연구소, [5]원에스티 기술연구소

Key words : QZS isolator, active control, wireless sensor interface

1. Introduction

The control systems using wireless sensors interface have been found many advantages for improving system performance [1]. In case of active QZS isolators which are widely used to isolate precision machinery from sensitive noise and vibration usually use inertial sensors for feedback compensation. However, the sensors with wire connection to controller easily cause unpredictable disturbance to QZS isolator since its stiffness is almost zero [2]. Moreover, the connecting wires will add more unknown damping and stiffness to system parameters which also lessen quality of active isolator performance. Consequently, wireless sensors communication for control system is considered in this paper for introducing to the active QZS isolator.

2. Active Control Model of QZS Isolator

2.1 The QZS Isolator using flexure

A mechanism of QZS isolator using flexure studied in this research is shown in **Fig 1**. The mechanism consists of three main parts: the horizontal coil spring, vertical coil spring and flexures. While the vertical coil spring produces positive stiffness, the notched flexure under compressive force of initially deformed horizontal spring generates a negative stiffness which allows obtaining quasi-zero stiffness (QZS) characteristics.

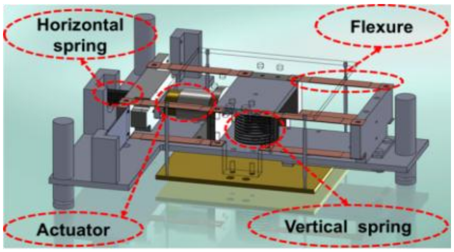


Fig. 1 QZS isolator using flexure

2.2 The motion equation of the isolator model

Based on the dynamic analysis of this isolator model that is done at other work [2], the motion equation of dynamic model is derived as Eq. (1):

$$m(\ddot{y}+g)+c\dot{y}+(k_{vs}+k_f)(y-y_{0vs})+T_2y^3 = f_cA_2y \quad (1)$$

where y is vertical displacement; y_{0sv} is initial deflection of the vetical spring, g = 9.81m/s^2 is garavitational acceleration, m is mass; c is system damping; T_1 and T_2 are coefficients of system dynamics; f_a is horizontal actuator force.

2.3 Active control rule

In studying case of the horizontal actuation, the actuator force is derived based on the dynamic equation (1).The control law is derived and converted to the horizontal actuator force as shown in Eq. (2) .

$$f_{nl} = a_1\frac{y}{\max(y,y_0)} + a_2\frac{\dot{y}}{\max(y,y_0)} - a_3\frac{y^3}{\max(y,y_0)} \quad (2)$$

where a_1, a_2, a_3 are Lyapunov control tuning gains.

The a_3 is gain for nonlinear feedback to cancel out the system nonlinear characteristic.

3. Wireless Sensor Model for Control System

The wireless sensor model includes two parts: sensing and control interfaces as shown in **Fig.2**. The sensing interface is the Texas Instruments ADS834 AD converter which offers a 16-bit conversion resolution and 4 sensing channels which is capable of digitizing any analog signal in the 0 – 5 V range at sample rates as high as 100 kHz. The control interface is designed with a 16-bit digital - to - analog converter (Analog Devices AD5542) which receives binary number from the microcontroller and converts them to analog voltage signals. The both use the Atmel ATmega128 microcontroller for computational core where embedded software is stored to execute data acquisition and transition. The Parani SD 200 modem is selected wireless communication channel.

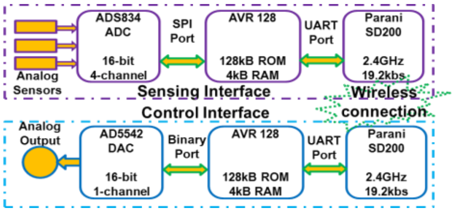


Fig. 2 Architecture of a wireless sensor interface

4. Experiment configuration setup

The experiment configuration consists of passive QZS isolator, digital controller, sensors, actuator, and wireless sensor interface module as shown in **Fig. 3**. Vertical passive isolator specification is summarized in **Table 1**. Several analog sensors are used for sensing system state data such as velocity sensor, acceleration sensor, and displacement sensor. The dSPACE controller computes and generates control signal from data provided by wireless sensor module. The control signal regulates the actuator through amplifier to stop vibration of the mass.

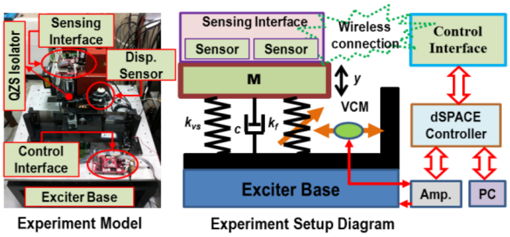


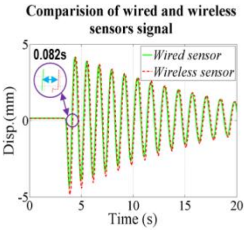
Fig. 3 Experimental setup

Table 1 Isolator specifications

Parameter	Value	Parameter	Value
m	25 - 40(Kg)	Stroke	±0.005(m)
k_{hs}	3.626x10^5(N/m)	k_{vs}	1.02x10^4(N/m)
c	2.87(Ns/m)	f_n	1 (Hz)

5. Experiment Result

The performances of the active QSZ isolator using wireless sensor interface are investigated with two criteria: impulse disturbance rejection and vibration transmissibility. The wireless sensor signal is compared with the wired sensor signal with time delay 0.082 s, as shown in **Fig.4.** The result of impulse disturbance rejection is shown in **Fig. 5** and the result of the vibration transmissibility is shown in **Fig. 6**. Both results show that the active QSZ isolator using wireless sensor interface has a good performance of vibration isolation. In time domain, settling time is reduced 75 percent by active control system comparing to the passive isolator. In frequency domain, the resonance magnitude is degraded almost 60 percent.



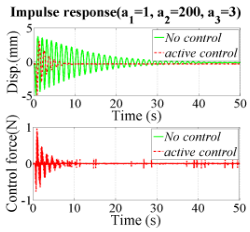


Fig.4 Signals verification **Fig.5** Disturbance rejection

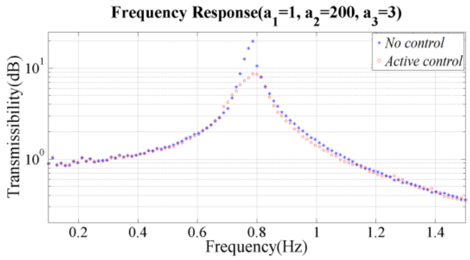


Fig.6 Experiment of system transmissibility

6. Conclusion

In this paper, the active QZS isolator using wireless sensor interface is experimentally investigated. The proposed wireless sensor interface is built and integrated in the digital control system. The experiment results with the active QZS isolator with wireless sensors show a good performance both time domain and frequency domain.

Acknowledgement

This research was supported by the MKE(The Ministry of Knowledge Economy), Korea, under the Convergence-ITRC (Convergence Information Technology Research Center) support program (NIPA-2012 C6150-1101-0004)supervised by the NIPA(National IT Industry Promotion Agency)

References

[1] C.H Loh, J.P Lynch "Experimental verification of a wireless sensing and control system for structural control using MR dampers", Wiley InterScience, **10**, 1002-682, 2010

[2] H.J. Ahn, "Performance limit of a passive vertical isolator", The Journal of Mechanical Science and Technology, **22**, 2357-2364, 2008

[3] P.V.Trung, K.R Kim, H.J Ahn, "Nonlinear Control of Active QZS Isolator Based on Lyapunov Function", International Symposium on Green Manufacturing and Applications, August 27-29, 2012