Mechatronics 21 (2011) 1055–1062

Contents lists available at ScienceDirect

Mechatronics

journal homepage: www.elsevier.com/locate/mechatronics

A three-axis vibration isolation system using modified zero-power controller with parallel mechanism technique

Md. Emdadul Hoque *, Takeshi Mizuno, Yuji Ishino, Masaya Takasaki

Department of Mechanical Engineering, Saitama University, 255 Shimo-Okubo, Sakura-Ku, Saitama 338-8570, Japan

ARTICLE INFO

Article history:
Received 18 September 2010
Accepted 21 May 2011
Available online 22 June 2011

Keywords:
Active vibration control
Modified zero-power control
Magnetic levitation
Modular vibration isolation
Parallel mechanism

ABSTRACT

This paper proposes a module-type three-degree-of-freedom vibration isolation system using modified zero-power control. Three vibration isolation modules are connected together using parallel mechanism to control 3-DOF motions. Each module consists of a common base, an individual middle mass and a common isolation table. The base to the middle mass is suspended by positive springs generated by active and passive system, and the middle mass and the isolation table is connected by negative spring realized by active-type modified zero-power control. The developed system could realize zero-compliance to direct disturbances as well as good ground vibration isolation. Furthermore, the isolation table is supported by a weight support mechanism for supporting heavy payloads. In the previous research, a concentrated middle mass with redundant actuators, in the vertical and horizontal directions, were used. Therefore, a vibration isolation system is proposed in this work using modular concept to overcome those drawbacks. Each module is controlled separately by decentralized control technique, and three modules can be used for three-degree-of-freedom of motion control. Therefore, no redundancy of actuator is occurred. Moreover, an improved zero-power controller is presented that can adjust negative stiffness instead of conventional zero-power controller. The results obtained from analytical and experimental studies show that the modular technique is reliable and efficient approach to vibration control, and represents a suitable alternative to the conventional active vibration isolation systems.

1. Introduction

Vibration isolation are strongly required in the field of high-resolution measurement and micromanufacturing, for instance, in the submicron semiconductor chip manufacturing, scanning probe microscopy, holographic interferometry, cofocal optical imaging, etc. to obtain precise and repeatable results. The growing demand for tighter production tolerances and higher resolution leads to the stringent requirements in these research projects and industries. The microvibrations resulted from the direct disturbance and/or the ground vibration should be carefully eliminated from such sophisticated systems. The vibration control research has advanced with passive and active techniques. Conventional passive technique uses spring and damper as isolator. They are widely used to support the investigated part to protect it from the severe ground vibration or from direct disturbance on the table by using soft and stiff suspensions, respectively [1,2]. Soft suspensions can be used because they provide low resonance frequency of the isolation system and thus reduce the frequency band of vibration amplification. However, it leads to potential problem with static stability due to direct disturbance on the table, which can be solved by using stiff suspension. On the other hand, passive systems offer good high frequency vibration isolation with low isolator damping at the cost of vibration amplification at the fundamental resonance frequency. It can be solved by using high value of isolator damping. Therefore, the performance of passive isolators are limited, because various trade-offs are necessary when excitations with a wide frequency range are involved.

Active control technique can be introduced to resolve these drawbacks. An active control system has enhanced performance because it can adapt to changes in the environment [3,4]. Although conventional active control system achieves high performance, it requires large amount of energy source to drive the actuators to produce active damping force [5–12]. Apart from this, most of the research projects use high-performance sensors, such as servo-type accelerometer for detecting vibration signal, which are rather expensive. These are the difficulties to expand the application fields of active control technique.

The development and maintenance cost of vibration isolation system should be lowered in order to expand the application fields of active control. Considering the point of view, a vibration isolation system have been developed using an actively zero-power controlled magnetic suspension system [13–15]. In the proposed system, eddy-current relative displacement sensors were used for

* Corresponding author. Tel.: +81 48 858 3453; fax: +81 48 858 3712.
E-mail address: emdadulhoque@gmail.com (M.E. Hoque).

0957-4158/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.mechatronics.2011.05.002