Form 2

Dissertation Abstract

Report no.	(Course-based) No. 949	Name	Mhia Md Zaglul Shahadat
Dissertation title	**Optimization of Vibration Control of Six-Degree-of-Freedom Vibration Isolation System**		

This dissertation is correspondence to research work conducted for the degree of Doctor of Philosophy (PhD). The research is entitled “Optimization of Vibration Control of Six Degree of Freedom Vibration Isolation System”.

During the last three decades, dimension accuracy requirements have progressed from micrometer range to the submicron and even nanometer range in several micro manufacturing industries, like as semiconductor industry, micro assembling industry, aerospace equipment industry and so on. Inherently, proper vibration isolation tables or platforms are essential in all this cases mentioned above. In this dissertation, the realization of active vibration isolation using different control techniques and the identification of the problems existed with the different control techniques and the minimization of these problems as well as improving the behavior of vibration isolation characteristics are sequentially encompassed.

On board disturbance and the disturbance transmitted from ground are the two main sources of vibration which are mainly responsible for creating unexpected motion and displacement in a system. Firstly, to obtain the vibration isolation characteristics using different control techniques, a three degree of freedom horizontal vibration isolation system is fabricated. The negative stiffness technique and displacement cancellation technique are individually applied to the developed system. It was observed from the experimental results that the system with displacement cancellation technique has good responses to isolate static disturbance whereas the system with negative stiffness technique could isolate dynamic disturbances sufficiently but the range of controllability is narrow. Moreover, the performance of a negative stiffness control system deteriorates significantly due to the nonlinearity caused by friction induced in the system. In this thesis paper, the friction-induced limit cycle in a negative stiffness control system is identified theoretically through describing function approach. The relationship between the magnitudes of the control parameters used in design the negative stiffness controller and the behaviors of the induced limit cycle are established. Finally, the theoretical limit cycle is verified with an experimental limit cycle measured by the time response to the self-oscillation of the system.

Moreover, the transient displacements which often hamper the objective function to acquire the vibration isolation system utilizing the both negative stiffness and displacement cancellation techniques. Moreover, these unpleasant responses are unacceptable in sophisticated micro manufacturing processes. To overcome this problem, a feedforward control linked to disturbance is added to the controllers of the both techniques in this study. Several experiments have been conducted regarding the performance of the developed system with feedforward control. It is observed that the both control techniques with feedforward control can suppress the transient peak significantly.

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However, to improve the transient characteristics by feedforward control, it is necessary to know the pattern and magnitude of disturbances earlier. But in most cases, the disturbances are random; hence, the applications of feedforward control linked to disturbance are limited. In this dissertation, the dynamic behaviors of the developed vibration isolation system against an unknown disturbance are improved by adding acceleration feedback to the controllers. However, the measurement of acceleration done by a conventional servo-accelerometer makes the system rather costlier as well as the application of a servo-accelerometer in acceleration feedback is limited. In the current research, this difficulty has been overcome by using low-cost MEMS accelerometer instead of servo-accelerometer. Nevertheless, the acceleration measured by MEMS accelerometer usually contains noise and the effect of this noise is reduced by considering acceleration feedback based on Kalman filter estimation signal instead of direct acceleration measured signal. From the experimental results, it is noticed that the Kalman filter estimated acceleration feedback added to the controllers has a significant influence to improve the vibration isolation characteristics.

Moreover a zero-compliance system with integral control accompanies power consumption to cancel disturbances. On the other hand, a system with zero-power control can avoid power consumption at steady-state. The simultaneous zero-power and zero-compliance is the ideal condition for a control system in respect to the low-cost control. However, the integral control (zero-compliance) and the zero-power control are incompatible in a conventional control system. The current research proposes a new magnetic suspension system which can provide zero-power and zero-compliance states simultaneously where the magnetic suspension system is connected with a normal spring (positive stiffness) in series and both are equal in magnitude of stiffness.

Researchers in the field of active vibration isolation typically tackle challenges to suppress the disturbances due to direct disturbance and ground vibration directing simultaneously from different axes-of-freedom. Therefore, a six-degree-of-freedom (6-DOF) active vibration isolation is explored using parallel mechanism in this research work as well.