Abstract of Dissertation

Fuzzy-Based Nonlinear Stabilizing Levitation Control of Multiple Electromagnets as Servo Actuators for Active Oscillation Suppression of Mechanically Flexible Structure

(弾性構造物能動的振動抑制のサーボ駆動のための多自由度浮上電磁石のファジー理論を用いた非線形安定化制御)

(エルカン　カディル)

Demands for high-performance vibration isolation and oscillation suppression systems have been increasing in various scientific and industrial fields such as high-precision control, semiconductor manufacturing and so on. There are two kinds of vibration to be reduced by a vibration isolation system. One is the vibration transmitted from ground or support point through the path of its post. The other is an impact caused by disturbance acting directly on the workspace. Lower stiffness of supporting suspension is better to reduce the former oscillation effects, such as automobile suspensions, while elimination of direct disturbance, later one, needs higher stiffness. Therefore, simultaneous suppression of both of base and direct disturbance effects on a workspace conflicts and requires a tradeoff between them. Conventional passive-type oscillation systems are composed of spring and dampers. Once, they are tuned, namely spring and damper parameters determined, their structure couldn't be changed anymore. This results degradation of suppression performance when the operation conditions are changed. In contrast to passive one, active-type oscillation suppression systems can modify their structure effectively when operation conditions are varied. Therefore, active type systems can easily break through this conflict.

Moreover, in the course of active vibration isolation, power consumption for control action and cost of sensors are significant problems to be solved effectively. Introduction of levitating electromagnets as actuators has some merits over the other candidate actuator types.

- ✓ Contact free operation
- ✓ No abrasion
- ✓ Only electrical power source necessity
- ✓ Suitability for some special applications such as clean room requirements.

Integration of permanent magnets into the magnet structure does not only decrease electrical power consumption but also brings about considerably reduced magnet size. From this point of views, in this study, an active vibration system utilizing hybrid electromagnets as actuators have been considered.

Prof. Mizuno proposed that controlling a hybrid electromagnet in zero power control mode

could give naturally negative stiffness contrary to normal spring when external force applied to a hybrid electromagnet. Furthermore, his idea has been revealing that serial connection of negative stiffness element with mechanical spring can turn into infinite stiffness by which eliminates both of the disturbance effects on the workspace. This idea has some pitfalls in the sense of practical realization.

⇒ Perfect equalization of negative stiffness of electromagnet with a spring might not be easy and practical every time.

⇒ Additional dynamics such as damper and a second mass would be introduced to the system. So that the system performance degrades from ideal one.

⇒ Electromagnet's nonlinearly has dominant effect when the gap length of the electromagnet takes values far away from linearization point.

To cure these pitfalls and also guaranty the system stability, in this research, gap length type servo control has been proposed. Summary, if the gap clearance of electromagnet tracks displacement of passive elements, constraint of negative and positive stiffness is automatically obtained. Maglev based actuators have substantial nonlinear features; therefore, stability must be assured. To improve the stability of such a system fuzzy-based control design procedure has been proposed, accordingly. Furthermore, to satisfy full redundancy multiple-arrangement of the electromagnets has been investigated in the form of several configrations. Outline of the dissertation as follows.

- Chapter one introduces the fundamental ideas and gives a brief sketch about current techniques of oscillation suppression.
- Chapter two investigates some important topologies of active oscillation suppression systems employing electromagnets as actuator and develops a mathematical model for triple star configuration of electromagnets in conjunction with passive elements.
- Chapter three explains fundamental controller and observer design approaches on the basis of linear control theory.
- Chapter four outlines fuzzy control approach in order to eliminate the drawbacks of linear counterpart.
- Chapter five confirms effectiveness of the proposed servo control based on fuzzy approach by simulation studies.
- Chapter six describes basics of the experimental test bench and furthermore releases experimental results supporting that the proposed idea of oscillation suppression is experimentally effective and plausible.
- Chapter seven draws some significant conclusion on the dissertation and shows future prospects.