Fuzzy Model Based Nonlinear Maglev Control for Active Vibration Control Systems

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Abstract. This short paper represents a nonlinear fuzzy modelling and tracking control methodology for active vibration control systems comprised of hybrid magnetic levitation (maglev) actuators in conjunction with passive elements. The proposed methodology combines the merits of fuzzy logic and well-known linear control theory by employing **TSK** (**T**akagi-**S**ugeno-**K**ang) fuzzy reasoning algorithm for both controller and observer designs on the basis of parallel distributed tracking and observation principle.

1 Introduction

Since, maglev-actuated active vibration control and isolation systems have some inherited merits, such as contact and dust free operation and only electrical power source necessity; they are candidates for many industrial applications. In maglev-actuated active vibration control and isolation systems, generally, the vibration effects are imposed to levitating part by two distinct disturbance sources, direct disturbance force and base or support displacements. Successful attenuation of the undesired effects of these disturbance sources very much depends on applied control policy and control quality of the actuator. The principle structure of the studied maglev-actuated active vibration control system is depicted in Fig. 1.

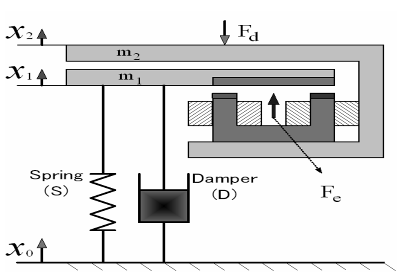

Figure 1: Principle configuration of investigated maglev-actuated active vibration control system.

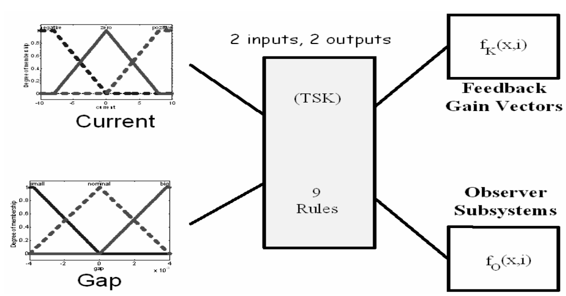

Figure 2: Illustration of TSK fuzzy reasoning system.

2 Linear Controller & Observer Design

The maglev actuator embeds PM's (permanent magnets) to provide gravity bias. Thereby, it is possible to employ zero power control based vibration control and isolation policy.[1] However, such policy will suffer mainly from positive and negative stiffness equalization constraint of the actuator & spring. To overcome this difficulty, passive elements' displacement following gap length type controller is proposed as vibration isolation policy which can be realized easily via state space integral control design. Besides, since the function of the actuator is to provide changeable stiffness, the desired stiffness value can be obtained by solely controlling the actuator and this will result in more relaxed controller and disturbance observer design. The system is unstable and shows fairly nonlinear feature due to the utilization of maglev actuator. Hence, the controller design process needs much more care. In linear control design, the nonlinear force equation of the maglev actuator is linearized around a specified operating point for tiny deviations, then, by using obtained current and displacement stiffness parameters for maglev actuator, the controller design issue is solved. The designed linear controller has a fixed structure and its performance is limited. Furthermore, the system can easily fall into instability for excessive change of gap clearance from specified linearization point.

3 Fuzzy Controller & Observer Design

The apparent nonlinearity of the actuator can be approximated via TSK fuzzy modelling technique for various operating points corresponding to local linear models. On the basis of parallel distributed tracking and observation principle, for each one of the local linear model, the passive element's displacement following gap length type controller (state space integral control) and zero order disturbance observer designs are carried out. Consequently, the designed controller gains and observer dynamics are threaded by fuzzy reasoning system to provide nonlinear control action to system. The concept is illustrated in Fig. 2.

4 Simulation Results & Experimental Consideration

Fig. 3 shows the simulation results of upper mass displacement for simultaneous excitation of stepwise direct disturbance force and sinusoidal base displacements. As experimental evaluation, we have designed a 3-DOF maglev actuator system and currently have been conducting some preliminary levitation experiments. In the final form of the paper, we have been planning to represent vibration control results and as well as discuss the stability issue.

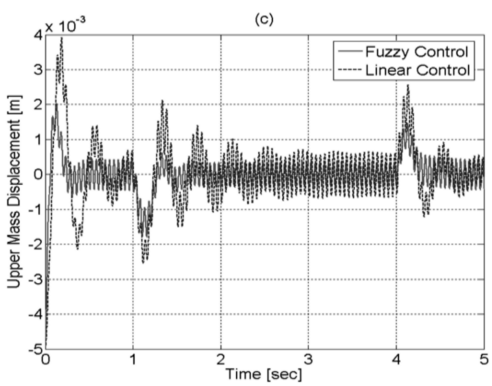

Figure 3: Simulation results of upper mass displacement under simultaneous disturbance excitations.

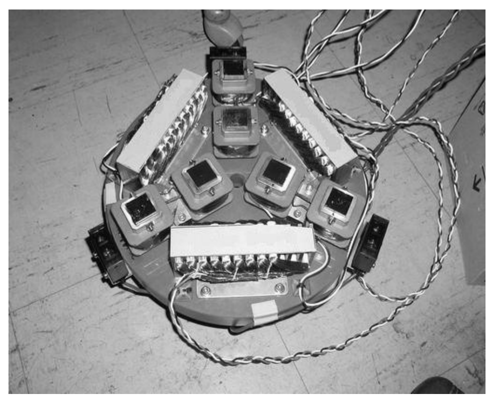

Figure 4: Photo of maglev actuator part of experimental test bench.

5 Conclusion

In this short paper, maglev actuated active vibration control concept has been introduced and the vibration control policies have been explained and compared on the basis of linear and fuzzy reasoning design point of views. Simulation results, Fig. 3, clarify the superiority of fuzzy based design over linear design counterpart.

References

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[2] Erkan K., Koseki T., “Magnetic Levitation Control for Active Vibration Systems Based on TSK Fuzzy Model”, Technical Meeting on Systems & Control, IEE Japan, SC-05-7~18, March 2005, pp.17-22.