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ROBUST VIBRATION CONTROL AND SYSTEM ANALYSIS OF SMART ANTISYMMETRIC TUBULAR STRUCTURES

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ABSTRACT

Smart structures research has found many applications in many engineering areas due to the effective integration of sensors, actuators, signal processing boards, and control algorithms with structural systems to achieve good performance and adaptability to the environmental changes. There are several requirements on the controllers used in this highly integrated system such as simplicity of hardware, reduced bandwidth, and less power consumption. These requirements translate into constraints on the actuator energy consumption and the complexity of the controller design. A truncated or reduced order model is used in the controller design to achieve lower order controllers. However, the resulting unmodeled dynamics when excited may degrade the performance or even lead to instability of the closed loop system. This phenomenon is known commonly as spillover effect in the structural control literature. One of the approaches to mitigate this difficulty and to avoid spillover effects due to the possible excitation of higher frequency modes and also due to the mathematical transformation of an infinite DOF system into a finite DOF model, and other uncertainties in the plant and control system dynamics, such as unmodeled dynamics, sensor noise, stochastic nature of dynamic inputs, and so on, is to design robust controllers treating the unmodeled dynamics as uncertainties, structured or unstructured. In this research, the use of a robust control technique for the vibration control of a adaptive asymmetric tubular structure based on a 2/D variational analytical formulation together with a finite element model described by a through-thickness layer wise (LW) and non-uniform quadratic electrical potential electrokinematics theory, equipped with piezoelectric actuators and sensors subjected to free, forced, impulsive, multi-harmonics, and white and colored disturbing vibrations is investigated. The smart tubular structure consists of an elastic core layer covered with inner and outer piezoelectric active layers. This model plays the role of both the load carrying system and the actuator/ sensor mechanisms in the feedback loop. The analytical/ numerical model of the distributed-parameter dynamical system having infinite kinematical degrees of freedom and described by a set of partial differential equations dependent on time and space variables is a three-layer elastopiezoelectric (Lead Zirconium Titanate, PZT for actuator layers, and Poly Vinylidene Fluoride, PVDF, for sensor layers) composite laminated tubular structure, first spatially discretized by a finite element procedure into a set of temporal

second-order ordinary differential equations, having multiple degrees of freedom (MDOF). This mathematical model in time domain is then converted into a set of decoupled second-order temporal ordinary differential equations in modal space domain. Here, based on nominal diagonalized mass, nominal diagonalized electromechanical stiffness, and nominal diagonalized damping energy mechanism matrices of the structure, the corresponding perturbed parameters are defined with bounded norms. The nominal model parameters of the tubular structure are determined by the material properties, geometry configuration, and boundary conditions using displacement-based finite element procedures. Since the physical parameters of the real structural system are not known exactly, we take a mean value for the determination of the nominal values and all other deviations are included in the uncertainty of the model. The exogenous influences acting on the system lead to errors in tracking capabilities of the controller. Parameter perturbations in the system can amplify significantly the effect of theses disturbances. Thus, the appearance of the model parameter uncertainties is a common task in shaping structural control system. For several reasons it is highly desirable to introduce structured uncertainties for the physical parameters of the system. To obtain the best possible performance in the face of the uncertainties, a robust H_∞ optimal control for active control of smart tubular structure has been considered in this research. The implementation of H_∞ control theory is motivated by the inability of the H_2 control theory to directly accommodate plant uncertainties. The robust control design will be formulated here within the framework of linear fractional transformation (LFT), which is particularly useful in the study of perturbations. After extracting the uncertainties from the model parameters of the system, they are applied to the block diagram of the parameters as exogenous inputs/ outputs by the use of LFT concept. Here the whole system including the plant, the control system together with the piezoelectric distributed sensor/ actuator dynamics are represented in the time domain by a set of first-order ordinary differential equations for system analysis and control design in state space description. Digital implementation and simulation of this assembly enhanced by A/D (sampler) and D/A (Zero-Order Hold, ZOH) converters, digital signal conditioners, and other digital systems, shows that H_∞ robust processor is not adequate. It seems we should resort to μ Synthesis and analysis control design.

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