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Editorial

Active Vibration Control in Mechanical Systems

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Mechanical systems such as vehicle suspensions, robot manipulators, and spacecraft are often required to operate with high performances. Strong shock and vibrations, which may quickly cause unacceptable system states, are perceived as the most important problems in mechanical system design. Active vibration control is the important branch of control theory and application, which mainly combines active vibration control mechanism with advanced control algorithms to improve system performance and reduce the influence of vibrations. Especially, due to possible structural nonlinearities and uncertainties in mechanical systems, both, active vibration control is still the challenging problem in the field of engineering control. This special issue aims at providing an opportunity for scientists, engineers, and practitioners to propose their latest theoretical and technological achievements in systems control, especially in the aforesaid aspects.

This special issue contains thirty-six papers, the contents of which are mainly summarized as follows.

"*Optimal vibration control for tracked vehicle suspension systems*" by Y. Liang and S. Wu develops a technique of optimal vibration control with exponential decay rate and simulation for vehicle active suspension systems. Mechanical model and dynamic system for a class of tracked vehicle suspension vibration control are established and the corresponding system of state space form is described.

"*Adaptive robust actuator fault accommodation for a class of uncertain nonlinear systems with unknown control gains*" by Y. Wu et al. presents an adaptive robust fault tolerant control approach for a class of uncertain nonlinear systems with unknown sign of high-frequency gain and the unmeasured states. In the recursive design, neural networks are employed to approximate the unknown nonlinear functions, K-filters are designed to estimate the unmeasured states, and a dynamical signal and Nussbaum gain functions are introduced to handle the unknown sign of the virtual control direction.

"*A modified D-K iteration approach for the decentralized H_∞ control of civil structures with parametric uncertainties*" by C. Qu et al. proposes a robust decentralized H_∞ controller design method to suppress the vibration of civil structures with the consideration of parametric uncertainties. The decentralized H_∞ controller design is motivated by the double homotopy approach, which approximates the bilinear matrix inequality derived from bounded real lemma to linear matrix inequality and gradually deforms a centralized controller to a decentralized controller. The centralized H_∞ controller can be designed for the civil structures with the parametric uncertainties through *D-K* iteration method in μ synthesis, which can consider the diagonal block pattern of the uncertain matrix.

"*Internal leakage fault detection and tolerant control of single-rod hydraulic actuators*" by J. Yao et al. provides the integration of internal leakage fault detection and tolerant control for single-rod hydraulic actuators. Fault detection is a potential technique to provide efficient condition monitoring and/or preventive maintenance, and fault tolerant control is a critical method to improve the safety and reliability of hydraulic servo systems. Based on quadratic Lyapunov functions, a performance-oriented fault detection method is proposed, which has a simple structure and is prone to implement in practice. The main feature is that when a prescribed performance index is satisfied, no fault is alarmed; otherwise, the fault is detected and then a fault tolerant controller is activated. The proposed tolerant controller, which is based on the parameter adaptive methodology, is also prone to realize, and the learning mechanism is simple since only the internal leakage is considered in parameter adaptation and thus the persistent exciting condition is easily satisfied. After the activation of the fault tolerant controller, the control performance is gradually recovered. Simulation results on a hydraulic servo system with both abrupt and incipient internal leakage faults demonstrate the effectiveness of the proposed fault detection and tolerant control method.

"*Adaptive PI-based sliding mode control for nanopositioning of piezoelectric actuators*" by J. Li and L. Yang proposes an adaptive proportion-integral- (PI-) based sliding mode control design (APISMC) used for nanopositioning of piezoelectric actuators (PEAs). Nonlinearities, mainly hysteresis, can drastically degrade the system performance. In addition to the model imperfection, hysteresis can be treated as uncertainties of the system. These uncertainties can be addressed by sliding mode control (SMC) since SMC is promising for positioning and tracking control. To further improve the response speed, suppress chattering, and reduce the steady-state error, the adaptive PI-based SMC is employed to replace the discontinuous control. Actually, the adaptive PI-based SMC offers a fast convergence of the sliding surface. Further, another advantage of the proposed controller lies in that its implementation only requires the online tuning PI parameters without acquiring the knowledge of bounds on system uncertainties. A linear second order system is utilized as the estimated model to compensate for the process nonlinearity and estimate the control gain. The robust stability of the APISMC is proved through a Lyapunov stability analysis. Simulation results demonstrate that the modified SMC is superior to the original one for both positioning and tracking applications. Compared with the original, the proposed controller provides better performance—less chattering, faster response, and higher precision.

"*Numerical and experimental modal control of flexible rotor using electromagnetic actuator*" by E. Koroishi et al. is dedicated to active modal control applied to flexible rotors. The effectiveness of the corresponding techniques for controlling a flexible rotor is tested numerically and experimentally. Two different approaches are used to determine the appropriate controllers. The first uses the linear quadratic regulator and the second approach is the fuzzy modal control. This paper is focused on the electromagnetic actuator, which in this case is part of a hybrid bearing. Due to numerical reasons, it was necessary to reduce the size of the model of the rotating system so that the design of the controllers and estimator could be performed. The role of the Kalman estimator in the present contribution is to estimate the modal states of the system and to determine the displacement of the rotor at the position of the hybrid bearing. Finally, numerical and experimental results demonstrate the success of the methodology conveyed.

"*Active disturbance rejection station-keeping control of unstable orbits around collinear libration points*" by M. Zhu et al. proposes an active disturbance rejection station-keeping control scheme for station-keeping missions of spacecraft along a class of unstable periodic orbits near collinear libration points of the Sun-Earth system. It is an error driven, rather than model-based control law, essentially accounting for the independence of model accuracy and linearization. An extended state observer is designed to estimate the states in real time by setting an extended state, the so-called total disturbance, that is, the sum of unmodeled dynamic and external disturbance. This total disturbance is compensated by a nonlinear state error feedback controller based on the extended state observer. Simulation results illustrate that the proposed method is adequate for station-keeping of unstable halo orbits in the presence of system uncertainties, initial injection errors, solar radiation pressure, and perturbations of the eccentric nature of the Earth's orbit.

"*An efficient spectral element model with electric DOFs for the static and dynamic analysis of a piezoelectric bimorph*" by X. Dong et al. presents an efficient spectral element model for static and dynamic analysis of a piezoelectric bimorph. It combines an equivalent single layer model for the mechanical displacement field with a sublayer approximation for the electric potential. It is shown numerically that the present spectral element model can well predict both the global and local responses such as mechanical displacements and natural frequencies as well as the electric potentials across the bimorph thickness. In the case of bimorph sensor application, it is revealed that the distribution of the induced electric potential across the thickness does not affect the global natural frequencies much. Furthermore, the effects of the order of Legendre polynomial and the mesh size on the convergence rate are investigated.

Of course, the selected topics and papers are not a comprehensive representation of the area of this special issue. Nonetheless, they represent the rich and many faceted knowledge that we have the pleasure of sharing with the readers. We hope that readers of *Mathematical Problems in Engineering* will find in this special issue not only the published papers on vibration control in various fields, but also important questions to be resolved such as vibration mechanism, the differences between semiactive control and active control, and advanced vibration control strategies.

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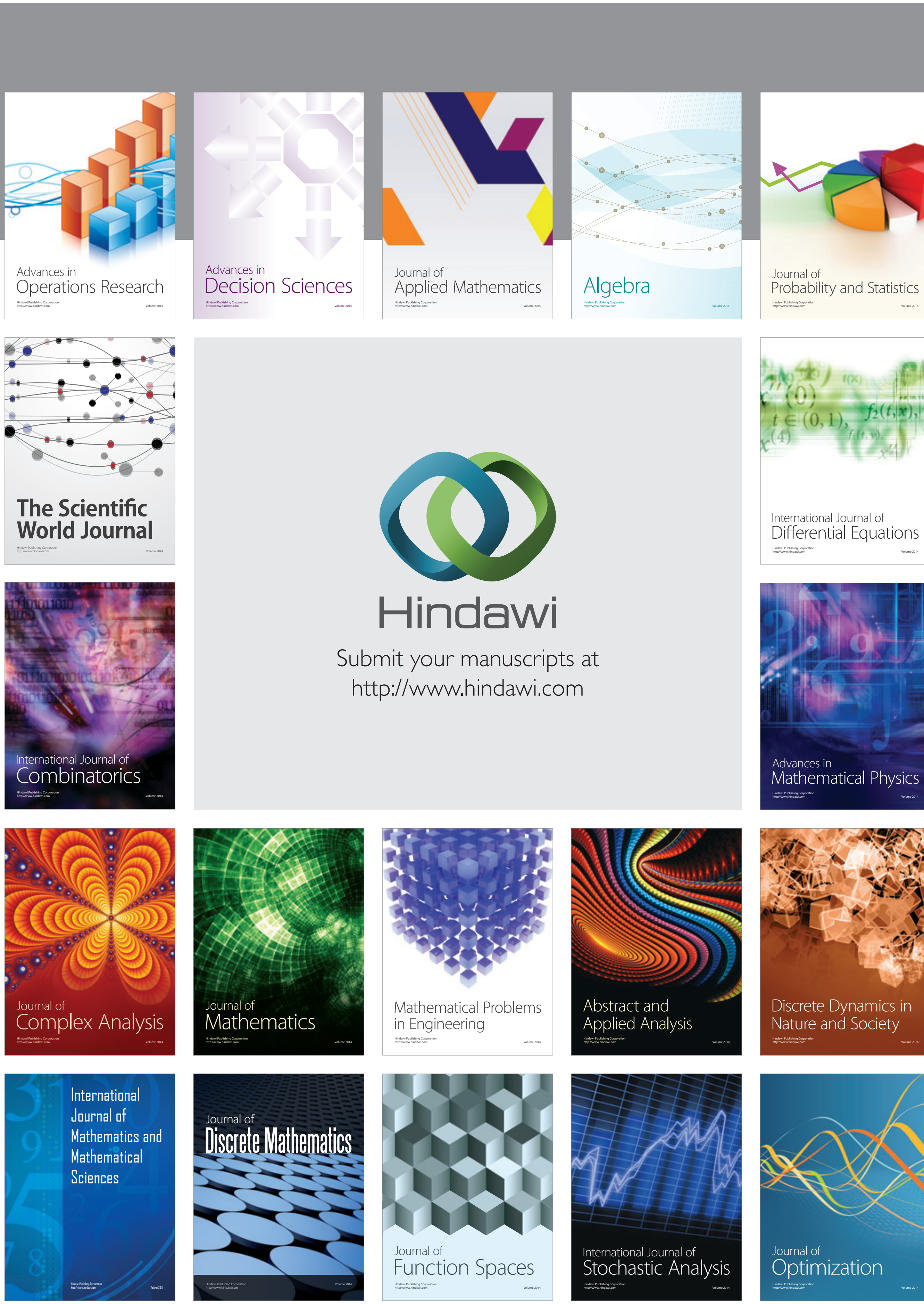

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