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Abstract: This thesis deals with the dynamics of a network of regular and chaotic nonlinear electromechanical systems consisting of electrical oscillators coupled either magnetically, electrostatically or piezoelectrically to mechanical oscillators with rigid and flexible arms. The understanding of such electromechanical devices in nonlinear regime is essential for the improvement of industrial and domestic products: shakers, mixers, vibration hammers and various machines such as for milling, impact print, sewing, washing and soil compaction tamping. This work investigates the dynamical behavior and synchronization in a network of mutually coupled electromechanical devices at the macro level (magnetic couping) and the micro level (electrostatic and piezoelectric coupling). The dynamics of micro-electromechanical systems with multiple functions in series are also studied.

The analytical investigation here makes use of the harmonic balance method to derive and discuss the amplitude of the harmonic oscillatory states. A nonlinear modal analysis approach is also applied to decompose the partial differential equation into a set of ordinary differential equations. The problem of chaos synchronization is described and converted into the analysis of stability (Lyapunov stability theory) of the system via its differential equations. The numerical procedure uses the Runge-Kutta Gill's fourth order method to approximate the solution of the system of ordinary differential equations.

Results of the study show that the effects of parameters variation and coupling strength lead to various types of bifurcation sequences (limit-cycles oscillations and chaos). By varying the coupling coefficient, the ranges for cluster and complete synchronization, both in the regular and chaotic states are found. According to analytical, semi-analytical predictions and numerical calculations, the transition boundaries toward the complete synchronization state are determined as a function of the increasing number of oscillators. The investigation shows that the more the oscillators are, the increase the value of the coupling coefficient for the complete synchronization in the network.

This work contributes to the theoretical analysis of this wide range of devices carried out in laboratories dealing with macro-, micro-structures and applications. Interesting results from the realization and experimental study of an electromechanical device with magnetic coupling have been observed in our laboratory. These results confirm and complement the theoretical study of the single device.