Modelling and nonlinear dynamics of magneto-electro-mechanical systems

The project is focused on mathematical modelling, numerical, analytical and experimental investigations of non-linear dynamics of mechanical systems subjected to influence of magnetic and electric fields. Using the already prepared experimental rigs and experience of the applicants in the field of methods of nonlinear dynamics and control, it is planned to fill the gaps in sufficient knowledge and uncertainties in the area lying between different disciplines of mechanics, electric and electronical engineering, automation and control.

In frame of the project there will be investigated different systems and experimental rigs: (A) single physical pendulum with magnetic forcing - where models of interaction of magnetic coil and permanent magnet, sufficient for efficient but reliable simulations and control of dynamics of mechanical systems with magnetic interactions will be developed and tested; (B) magnetically driven coupled pendula – where models of interaction of magnetic coil and permanent magnet are further developed and tested during investigations of nonlinear dynamic of coupled pendula; (C) magnetically driven coupled pendula subjected to tilted excitation – investigations of such problems like controlling the dynamics of the magnetic pendulums by the use of feedback parametric damping, tilted or magnetic excitation; (D) double planar pendulum with magnetic interactions – it is planned further development of reduced models of magnetic forces generalized to two-dimensional configuration space as well as the use of this model in analytical and numerical investigations of nonlinear dynamics and bifurcation control of the system; (E) pendulum driven by crank-shaft-slider mechanism and DC motor with magnetic interactions – analysis of problems of mutual interactions between the oscillatory system and the energy source of limited power and control of bifurcation dynamics by the use of current in the coils as input signals; (F) multi-parameter oscillator based on a three-phase core-less linear motor – the aim is accurate development of magnetic fields' functions for all electric machines and other devices where magnetic interaction plays an important factor; (G) development and mathematical modelling of magnetic springs – the purpose of this stage is construction and investigation of magnetic springs; numerical and experimental investigations in the area of control of energy flow and bifurcation dynamics of the system of serially connected carts using springs with magnetic coils; (H) investigation of stability in a hybrid stepper motor – where modelling and analysis of nonlinear dynamics of stepper motors will be performed; (I) nonlinear dynamics of spring pendulums embedded in gravity, electrostatic and electromagnetic fields - analysis of the occurrence of multiple resonances, anti-resonances, synchronization effect, energy transition between oscillators, scenarios of transition from regular to chaotic motion and approximate asymptotic solution of the non-steady state motion of different pendulum systems, including those excited by stick-slip oscillations; (J) parametric magnetic pendulum – detection of the resonance conditions and analysis of the chosen resonance case.

An immense development of today's sciences and technology requires matching and mutual feedbacks of both research branches to guarantee today's high level of living of our civilization. However, complexity of evolution behaviour of real-world systems needs novel methodological approaches spanned by interdisciplinary exchange of ideas, matching of different sciences (mechanics, physics, applied mathematics, electric and electronical engineering, automations and control, etc.) and dedicated approaches aimed on high level deep modelling of the processes behaviour including on-line control of the studied processes.

The presented literature survey prove that topic undertaken by the project is a current research topic and of great importance, both from the point of view of pure science as well as applications in technology. The proposed project embraces a valuable self-contained group of problems exemplifying the original methodological approach to fill existing gaps of sufficient knowledge and/or uncertainties in non-linear dynamics exhibited by the studied electro-magneto-mechanical systems. It should be emphasized that our project is aimed on the fundamental studies matching non-linear dynamical phenomena with a help of the concepts coming from mechanics, mechatronics and physics.