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Research of the dynamics of a physical pendulum forced with an electromagnetic field

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Abstract: In this paper, both experimental and numerical results of the dynamics of a pendulum with a neodymium magnet and an aerostatic bearing are presented. The experimental stand includes the pendulum with the neodymium magnet at the end of the rod, whereas four electric coils are placed underneath. The pivot of the pendulum is supported on the aerostatic bearing. As a result, dry friction resistance in the pivot joint can be negligible and it has only a viscous character. The electric current with a given frequency and duty cycle and of a square waveform flows through the coils. Interaction between the neodymium magnet and the electric coils leads to the forced angular motion of the pendulum with the neodymium magnet. Both mathematical and physical models with experimentally confirmed system parameters are derived. The results of the simulation and experiment showed rich dynamics of the system, including various types of regular motion (multi-periodicity) and chaos.

Keywords: nonlinear dynamics, electromagnetic field, physical pendulum, aerostatic bearing

1. Introduction

Non-linear character of the motion and very simple construction make the pendulum an often used object of many investigations of dynamics systems [1, 2, 3]. On the base of the interaction between electric and magnetic fields, for instance an electric motor works, which proves the great popularity of using this dependency nowadays [4, 5, 6, 7]. Physical pendulum driven by electromagnetic field research are willingly extended to create more complex systems and relationships [8, 9]. In this paper, mechanical energy is produced using the above-mentioned interaction in order to force motion of the physical pendulum. The axis of pendulum's rotation coincides with the shaft's axis suspended in the pressured air generated by an aerostatic bearing. This system is coherent, so the pendulum's motion is closely dependent on the force generated by the electromagnetic field, but also on the distance from the coil. The object of studies in this article are the presented dependencies.

2. Results and Discussion

In the presented paper the system of a physical pendulum supported by aerostatic bearing and subjected to an asymmetric repulsive magnetic field was studied. Physical model of the system is shown in Fig. 1. The magnetic field was induced by the four electric coils powered by a rectangular current signal with controlled values of frequency, duty cycle and amplitude. The magnetic field was alternating which directly influenced the dynamics of the pendulum.

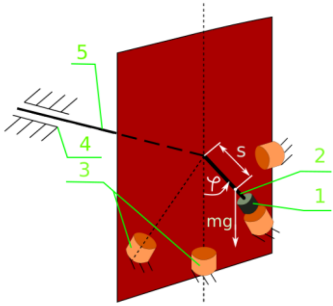

Fig. 1. Physical model of the system: 1 – neodymium magnet, 2 – pendulum, 3 – electric coils, 4 – aerostatic bearing, 5 – shaft.

3. Concluding Remarks

The physical and mathematical models of the considered system were developed. The numerical and experimental time histories plots of periodic motion with good agreement were shown. The bifurcation analysis was presented for increasing and decreasing paths of frequency as a control parameter. A set of phase plots were used to show the evaluation of chaotic motion. The system and experimental stand offer many opportunities for further research.

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