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Dynamics of a fluttering micro-robot in the proximity of an ideal solenoid: two "virtual" laboratory experiments

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Electromagnetism plays an important role in the understanding of many biological phenomena. One common use of electromagnetic fields is found in bio-inspired micro-robotics [1], where Lorentz-type forces can be used to influence significantly, and even control, the movement of robots. However, the magnitude of the correction on the robots' trajectories due to the electromagnetic interactions depends on the way in which locomotion occurs [2].

One outcome of some locomotion mechanisms, found in the context of micro-swimmers at low Reynolds numbers, is the onset of flutter instability [3]. Fluttering can be generated when the propulsion thrust, exerted e.g. by the fluid surrounding the robot, exceeds a certain threshold.

In this presentation we provide two "virtual" experiments involving a fluttering micro-robot that interacts with an ideal solenoid placed in its proximity [4]. Our goal is twofold: first, to show that, by using micro-robots, it is conceivable to detect an important electromagnetic effect, directly imputable to the vector potential [5], as discussed in [4]; second, to determine how the Lorentz force generated by the ideal solenoid influences the dynamics of the micro-robot. For our purposes, the design of our considered micro-robot takes inspiration from a variant of Ziegler's double pendulum investigated in a work by Cazzolli et al. [6].

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References

[1] Shen, H., Cai, S., Wang, Z., Ge, Z., Yang, W., "Magnetically driven microrobots: Recent progress and future development", *Materials & Design*, **227**, 111735 (2023).
[2] Zhang, L., Peyer, K. E., Nelson, B. J., "Artificial bacterial flagella: Fabrication and magnetic control", *Nano Letters*, **9**, 3663–3667 (2009).
[3] Boiardi, A. S., Noselli, G., "Minimal actuation and control of a soft hydrogel swimmer from flutter instability", *J. Mech. Phys. Solids*, **191**, 105753 (2024).
[4] Pastore, A., Harrop, J.C., Bigoni, D., Grillo, A., "Dynamics of a charged Ziegler's double pendulum under the joint action of a follower force and Lorentz force", (2026) *To be submitted*.
[5] Rousseaux, G., Kofman, R., Minazzoli, O., "The Maxwell-Lodge effect: significance of electromagnetic potentials in the classical theory", *Eur. Phys. J. D*, **49**, 249–256, (2008).
[6] Cazzolli, A., Dal Corso, F., Bigoni, D., "Non-holonomic constraints inducing flutter instability in structures under conservative loadings", *J. Mech. Phys. Solids*, **138**, 103919 (2020).