# EMERGENT ADAPTIVE BEHAVIORS

## Embracing fluid-structure interactions to achieve new functionalities

PhD opportunity at the laboratory: Ladhyx, Ecole Polytechnique
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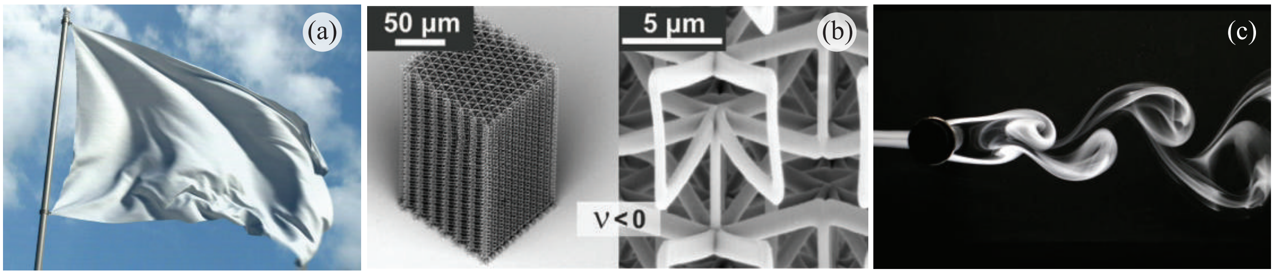


Figure 1: (a) Common outcome of fluid/structure coupling: flag fluttering in the wind. (b) Mechanical metamaterial which expands in the transverse direction (instead of compressing) when stretched vertically [1]. (c) Vortex wake behind an object, that can induce lateral vibrations (image from smart-flow.de).

A deformable object interacting with the surrounding fluid exhibits fascinating behaviors. To convince yourself, you can look at a flag that spontaneously starts fluttering in strong winds (Fig 1.a), or a fish moving in water [2]. Those dynamics are often unwanted in construction, and engineers build structures accordingly to avoid catastrophic events like the destruction of Tacoma bridge due to aero-elastic instabilities. This PhD project will take the opposite approach. Instead of minimizing those couplings, structures will be designed so as to purposedly harness fluid/structure interactions. The associated effects will be exploited to tailor desired mechanical behaviors and build objects with new functionalities.

This project is rooted in the expanding context of architected materials, like the one shown in Fig 1.b. Those metamaterials are assembled out of building blocks -like Lego bricks- that are specially designed to achieve unique bulk properties, such as invisibility cloaking in optics or the mechanical ability to expand in the transverse direction when stretched (see Fig 1.b). Using a similar approach, the goal of this PhD is to develop and study multi-scale systems whose global properties result from the local interaction of its building blocks with the surrounding fluid.

Coupling with fluids is a promising addition to the design toolbox because of its rich phenomenology. For example, a building block can be driven to vibrate in a flow (Fig 1.c), or alternatively exert forces in the matrix structure that vary with its fluid environment. Unlike a traditional inert object, the mechanical properties of the system then spontaneously change in response to external variations. You could then imagine adaptive systems that are able to detect changes in their environmental conditions and spontaneously adapt. Such object could stiffen up in strong winds to protect itself, or act as an adjustable wave guide that propagates signals differently depending on the fluid flow it is immersed in.

This PhD will combine experiments and theory. The candidate will have a pronounced taste for experimental work, and will build and study set-ups to understand how specific morphologies allows for tailored functionalities. To develop a deeper understanding, this experimental work will be coupled to theoretical and numerical models, relying on tools developed at LadHyX for deformable structures under fluid loading [3]. Strong skills in fluid mechanics, continuum mechanics and/or fluid/structure interaction would be an asset.

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[1] Bückmann T. et al (2012). Tailored 3D mechanical metamaterials made by dip-in direct-laser-writing optical lithography. *Advanced Materials*, 24(20), 2710-2714.

[2] Ramananarivo S., Godoy-Diana R., & Thiria B. (2013). Passive elastic mechanism to mimic fish-muscle action in anguilliform swimming. *Journal of The Royal Society Interface*, 10(88), 20130667.

[3] Leclercq T. & de Langre E. (2016). Drag reduction by elastic reconfiguration of non-uniform beams in non-uniform flows. *Journal of Fluids and Structures*, 60 :114-129.