INTERNSHIP/PHD

FLOW-INDUCED INSTABILITIES OF KIRIGAMI SHEETS

Supervisors: Sophie Ramananarivo, sophie.ramananarivo@polytechnique.edu
Agathe Schmider, agathe.schmider@polytechnique.edu
Start date: anytime from Jan. 2024
Host laboratory: LadHyX, Ecole Polytechnique

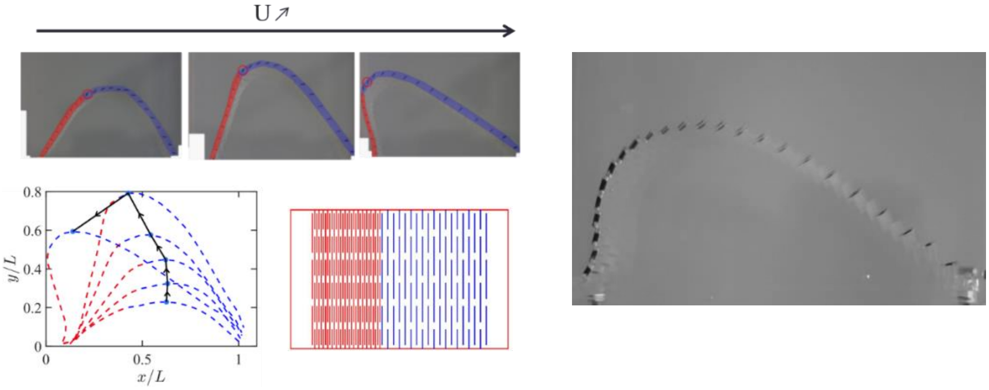

Figure: (left) Sudden shape change of a kirigami sheet upon increasing the flow speed. (right) Flow-induced vibrations.

Context: In the field of engineering, there is a growing interest for flexible components over rigid ones, in devices designed to operate within fluid flow. The capacity of these components to deform makes them more resilient and adaptable to fluctuating fluid environments. Additionally, these shape-shifting properties can improve aerodynamic performance and fulfill functional roles, such as acting as a valve, without the need for external actuation mechanisms. Nevertheless, a major challenge lies in understanding how these flexible objects deform when subjected to fluid loading and in being able to control their responses. One promising approach involves applying the kirigami technique, which draws inspiration from the Japanese art of paper cutting. Research conducted at LadHyX has demonstrated that kirigami offers a means to pre-determine how sheets deform in response to fluid flow based on their cutting patterns [1].

Although our primary focus has been on analyzing static and quasi-static behaviors, understanding the dynamical fluid-elastic response is also critical. Slender structures subjected to transverse or axial flow are indeed susceptible to self-induced oscillations and buckling [2], which could potentially compromise their structural integrity or functionality. Alternatively, rather than designing structures to avoid instability, we can deliberately trigger controlled oscillations for energy harvesting, by means of piezoelectric transducers, for example. Instabilities also offer a means to deliberately induce sudden, controlled changes in shape in response to minor variation in fluid loading to serve different purposes. Both such rapid changes in shape and fluid-induced vibrations have been observed in experiments at LadHyX

Goals: The objective of the internship is to investigate static and dynamic flow-induced instabilities in such porous and elastic structures. We will experimentally characterize the mechanical response of kirigami sheets to flows (and conduct flow visualizations), as a function of the cutting pattern and fluid velocity. This experimental study will be combined with theoretical modelling and stability analysis to better understand the fluid-structure mechanisms underlying these instabilities.

Profile: Candidates should have a good training in Fluid mechanics, Soft Matter or Continuum mechanics. A strong taste for both experiments and theoretical analysis is a plus. *PhD opportunity after the internship.*

[1] Marzin, T., Le Hay, K., de Langre, E., Ramananarivo, S., 2022. Flow-induced deformation of kirigami sheets. Phys. Rev. Fluids 7, 023906.
[2] M. P. Paidoussis, Fluid-structure interactions: slender structures and axial flow, Academic press, 1998.