Drag force tuning through passive adaptive Origami structure

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Origami-like geometries occur in a lot of natural settings like in leaves or foldable insect wings. While the main apparent purpose of such folding is to assist deployment, structures after that retain pleated morphologies that may affect the operation of wings in flight or the wind resistance of tree leaves. Thus, it becomes important to understand the impact of folds on fluid–elastic processes. In our study, we incorporate a network of creases into the structure. The addition of folds enables the programming of the structure's response to fluid loading, leading to greater levels of deformation.

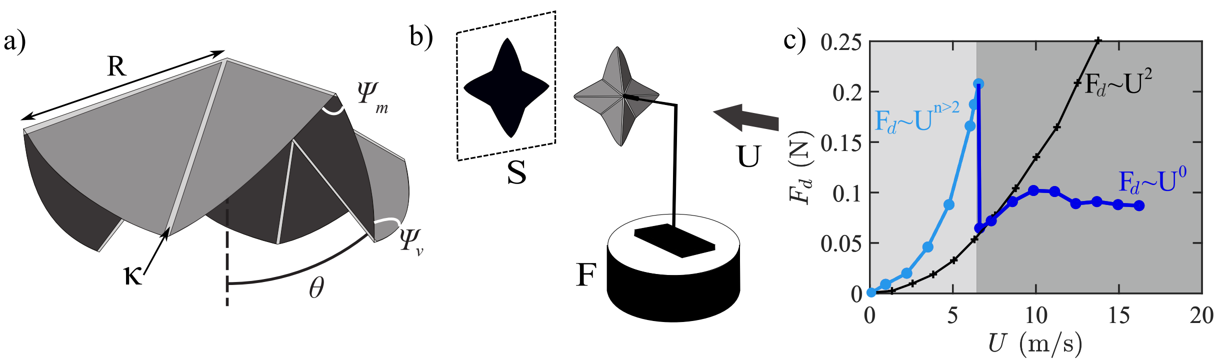

Figure 1. a) Folded state characterized by the opening angle θ between a valley fold and the central axis passing through the vertex. The angles of mountain and valley folds, ψ_m and ψ_v, respectively. b) An experimental system with the origami cell held in an incoming uniform airflow with speed U. The drag force F_d is measured by a force balance, while simultaneously extracting the frontal area S to quantify shape changes. c) Evolution of the drag force with U at two deformation phases (shaded area). It is compared to a rigid origami (in black line) with the same cell parameters

By mixing experiments on the aerodynamics of an elementary origami waterbomb cell and simplified theoretical models we probe the response of a folded structure in a controlled fluid flow environment. The waterbomb folding, as shown in Figure 1a, is an origami unit featuring an even number of uniformly spaced folds that radiate from a single vertex. This crease pattern can be reduced kinematically to a single degree of freedom, represented by the opening angle θ. The unit is bistable and can transition between its two stable states by snapping around the unstable flat configuration i.e, $\theta = 90^o$. This non-trivial folding pathway enables a large change in shapes and allows the emergence of a new drag law. The opening phase of the cell results in a stronger drag evolution (light grey area of the Fig1) than that of a bluff body ($F_d \approx U^2$), while the closing phase witnesses a significant drag reduction (dark grey area of the Fig1c and [1]) after a large drag drop around the unstable snapping. By varying the parameters of the origami cell, the drag law can be programmed, and adding folds to the structure highlights its relevance as a passive drag control method.

References

1. T. Marzin, E. de Langre & S. Ramananarivo , Shape reconfiguration through origami folding sets an upper limit on drag, *Proceedings of the Royal Society A*, 478(2267) (2022).