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Wind Energy Harvesting using a Kite

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Using kites to collect wind power and generate energy has been intensively studied in the last decade, see *e.g.* the survey by M. Diehl *et al.* in [1]. In the framework of the KEEP (Kite Electrical Energy Power) funded by CNRS and gathering researchers from ENSTA Bretagne (well acquainted with the topic after previous studies on kites [2], most notably for boats [3]) and Université Côte d'Azur, we are interested in the analysis of a simple device composed of a kite attached to an arm; having the kite running along a well chosen curve will move the arm and generate electric power. We first build a simple point-mass mechanical model where the kite motion is prescribed to a conical surface modelled on an eight curve. The resulting differential equation is a dimension 2 second order ODE, which rapidly converges to a limit cycle. We perform optimisation on the limit cycle to obtain maximum average power and report on the sensitivity of the power generated by this cycle with respect to the design parameters.

Ongoing work consists in devising an unconstrained control model for the arm + kite device, and in verifying that plugging the force extracted from the previous model into the new controlled one indeed allows to initialise the search for a *controlled* periodic cycle.

We extensively use Julia capabilities to perform integration (DifferentialEquations.jl, DiffEqCallback.jl), automatic differentiation (ForwardDiff.jl), root finding (NonlinearSolve.jl), and optimisation (ADNLPModels.jl).

References

[1] Ahrens, U.; Diehl, M.; Schmehl, R. (eds.) *Airborne Wind Energy*, Springer, 2013

[2] Desenclos, K.; Nême, A.; Leroux, J.-B.; Jochum, C. A novel composite modelling approach for woven fabric structures applied to leading edge inflatable kites. *Mech. Composite Materials* **58** (2023), no. 6, 867–882.

[3] Podeur, V.; Merdrignac, D.; Behrel, M.; Roncin, K.; Fonti, C.; Jochum, C.; Parlier, Y.; Renaud, P. Fuel economy assessment tool for auxiliary kite propulsion of merchant ship. *Houille Blanche* **1** (2018), 5–7.

Primary author: BAVOIL, Antonin (Université Côte d'Azur, CNRS, Inria, LJAD, McTAO)

Presenter: BAVOIL, Antonin (Université Côte d'Azur, CNRS, Inria, LJAD, McTAO)