Dynamics and Control of Bio-inspired UAVs

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Grant number 22/03128-7: *Aeroelastic analysis and control of bio-inspired UAVs for engineering applications*

Outline

Motivation

Aeroelastic modeling

Applications

Bio-inspiration



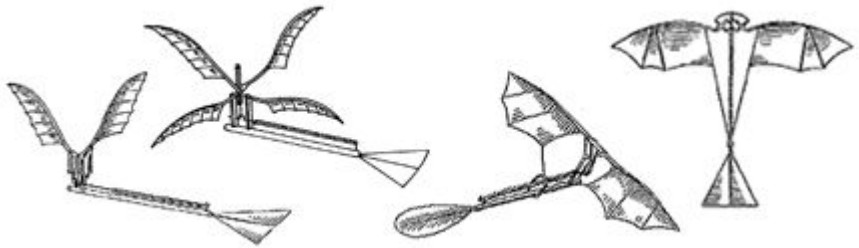












Alphonse Penaud and Hureau de Villeneuve, in 1872 (rubber-powered)



Lawrence Hargrave, in 1890 (steam and compressed air)



James DeLaurier and Jeremy Harris, in 1991 (internal combustion)

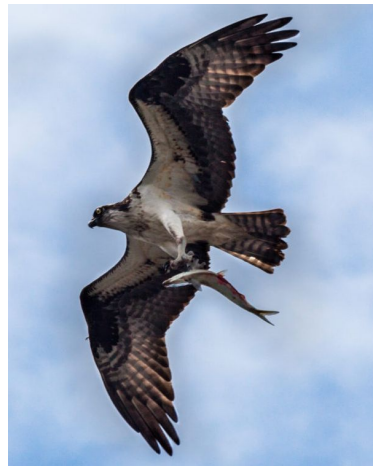


Albert Kempf, in 1998 (electric power)

Features

- Advantages
  - Lower noise generation
  - Maneuverability
  - Reduced noise
  - Camouflage
- Uses
  - Military applications
  - Ecological researches

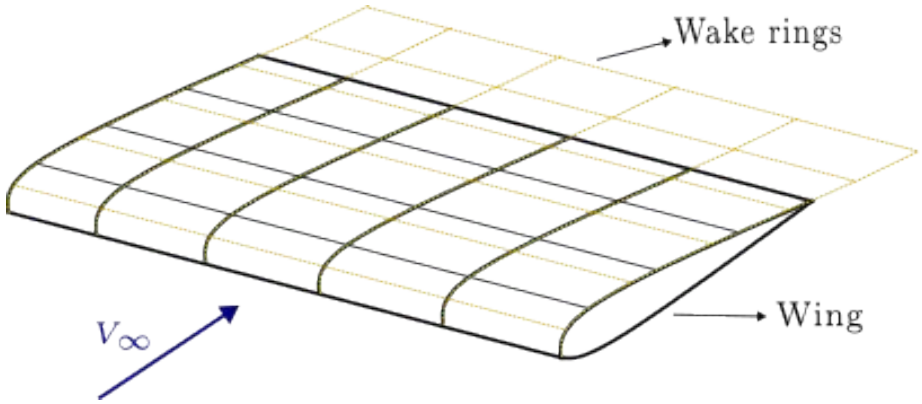


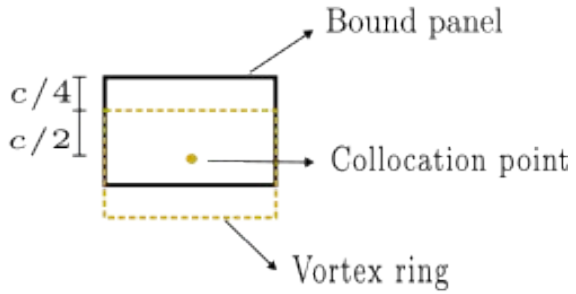


- Challenges
  - Complex motions

Aerodynamics

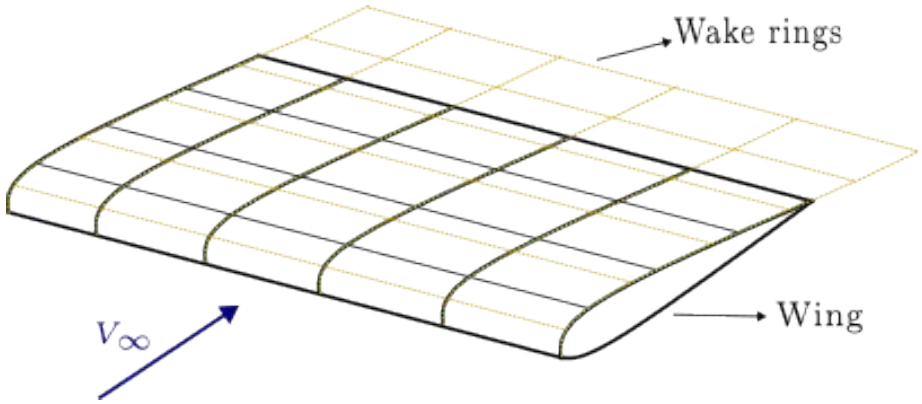
- Potential flow;
- Panel method;
- Unsteady Vortex Lattice Method.
- Vortex rings;
- Induced velocities;
- Collocation points.

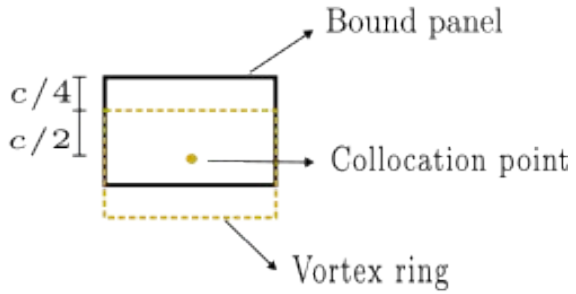




Aerodynamics

- Potential flow;
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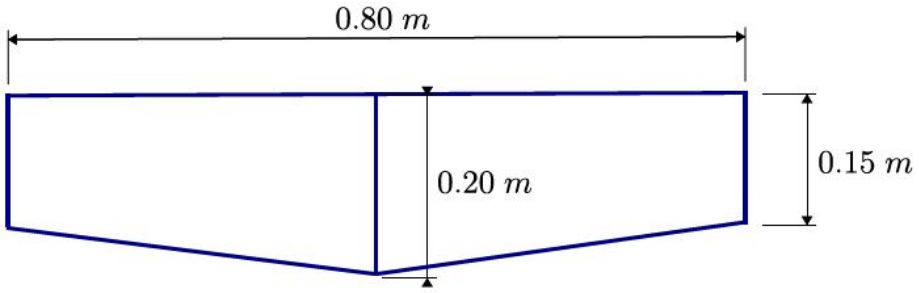




Aerodynamics

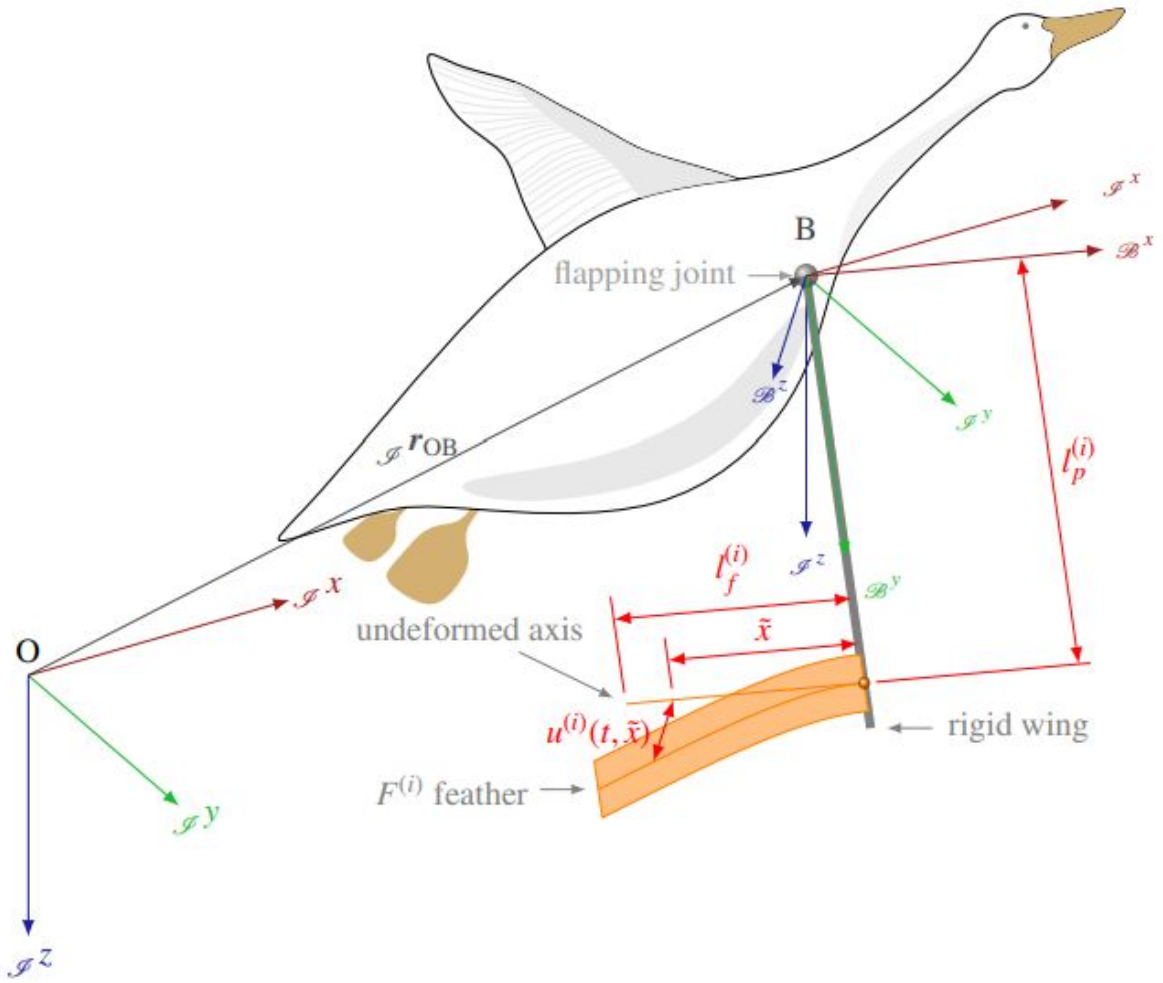
- Bio-inspired geometry
- Amplitudes, frequencies, phase
- Motions: flap, pitch and heave
- Force coefficients and efficiency







Structural dynamics



ventilations, gaps

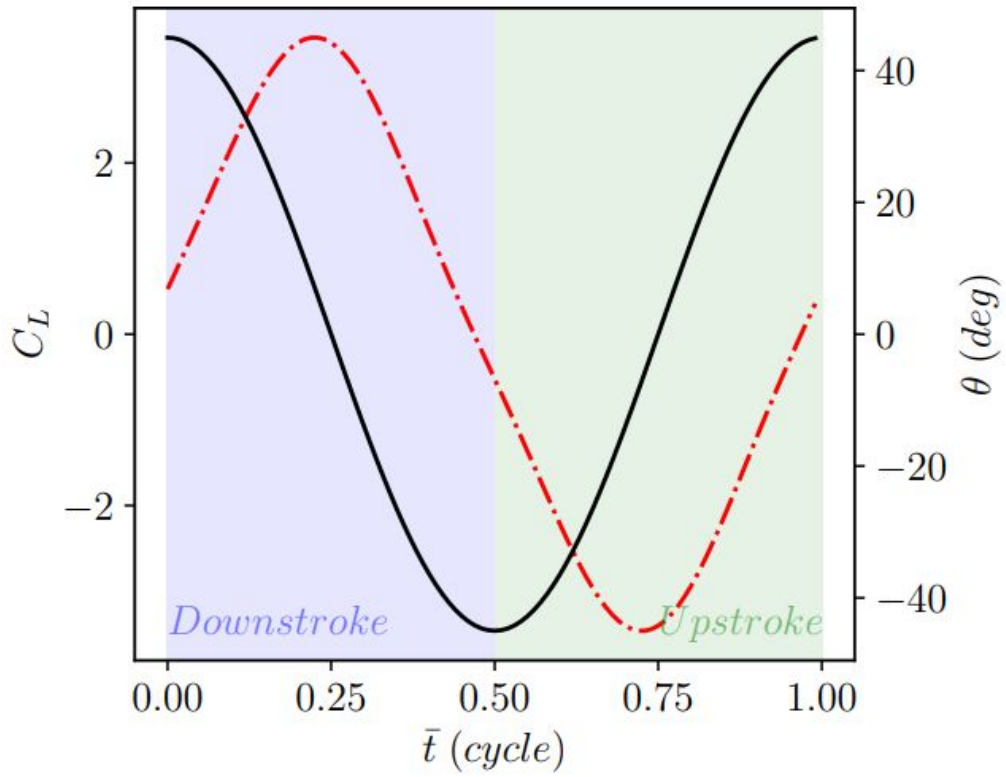


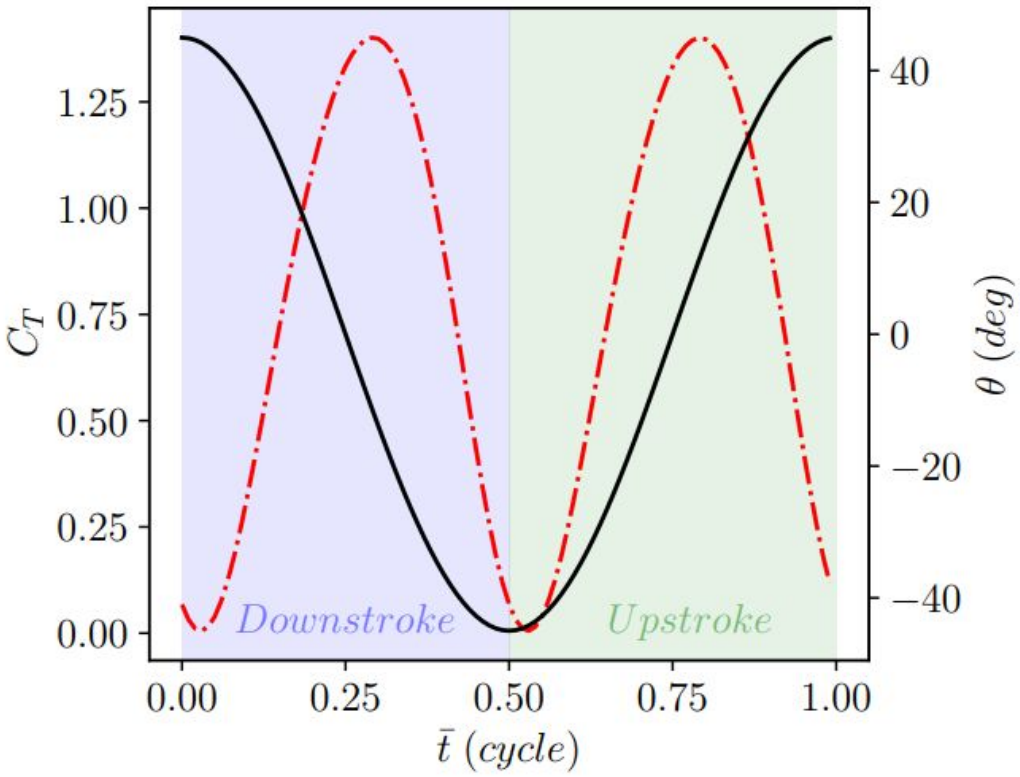
(a)



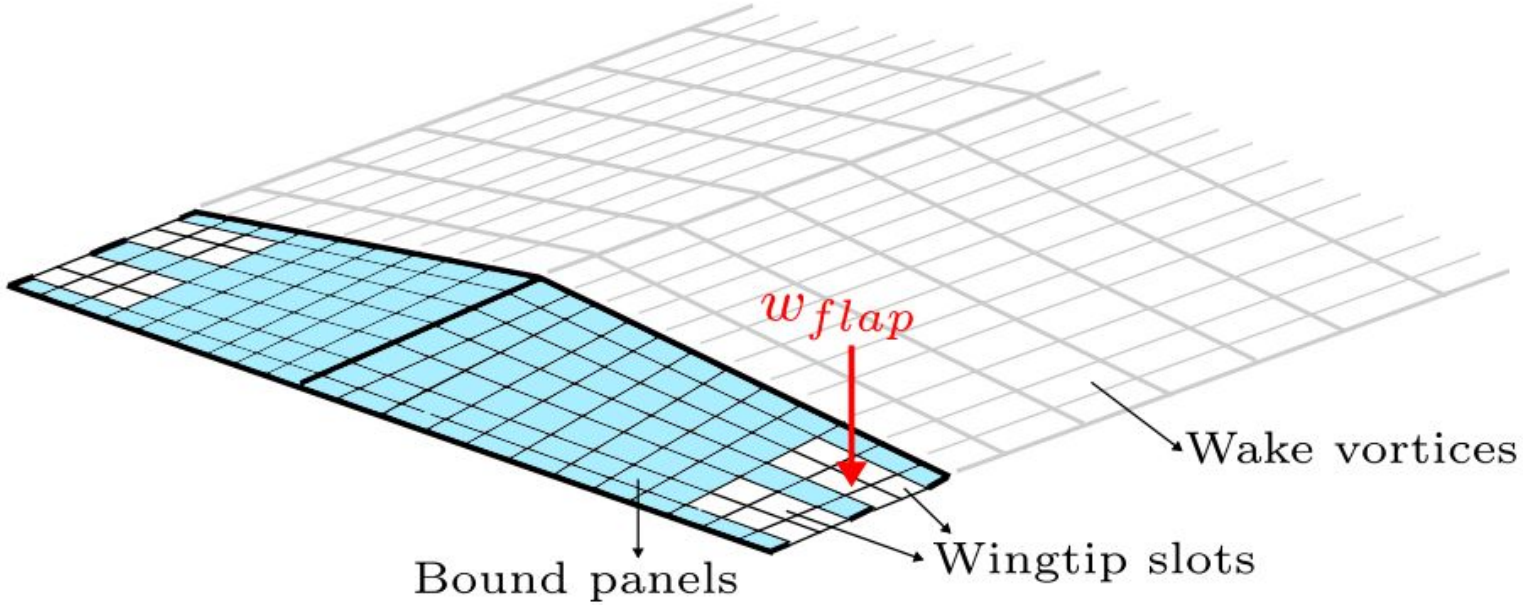
(b)

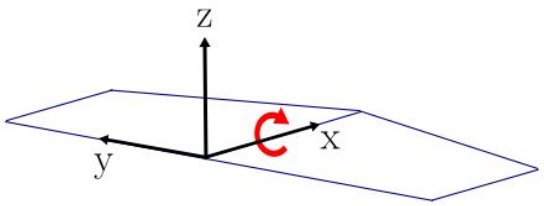
Aerodynamics



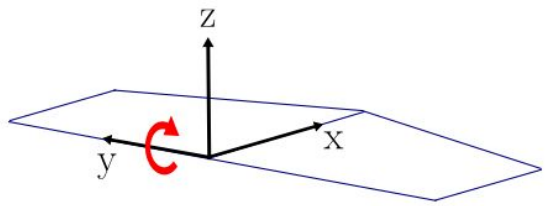


Aerodynamics

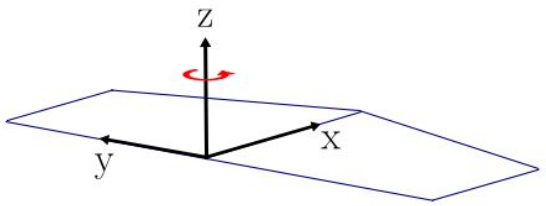




(a) Flap

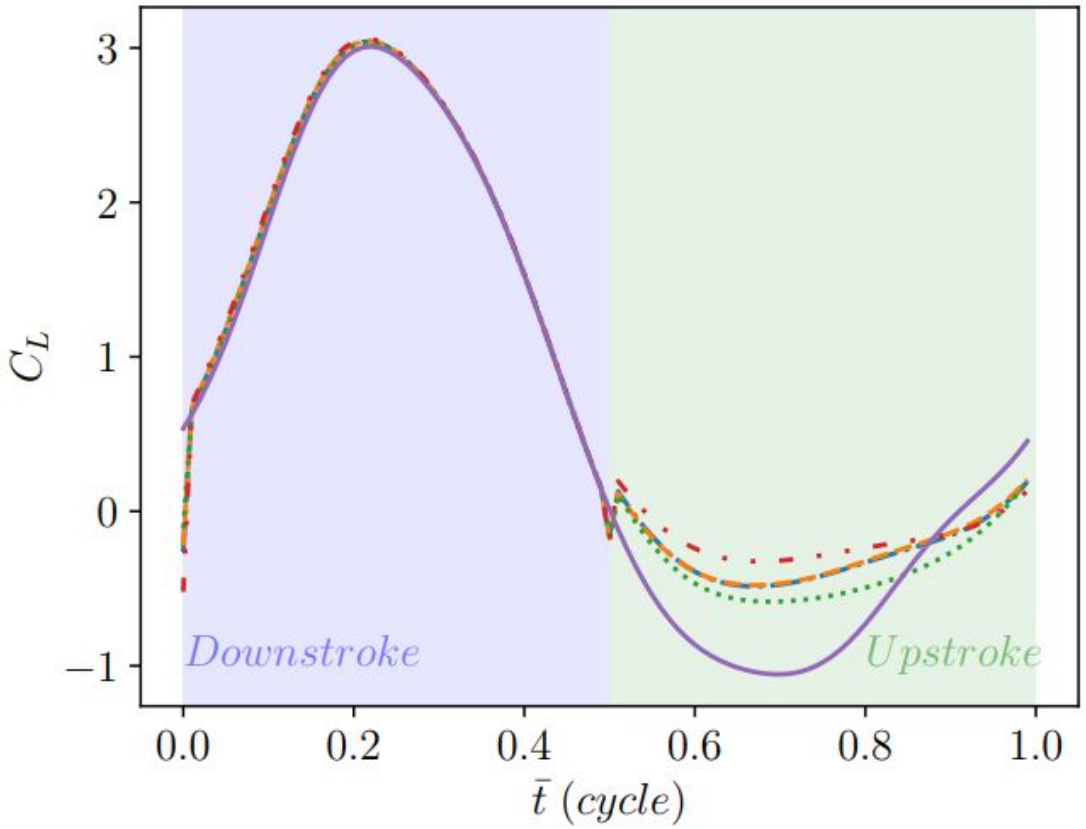


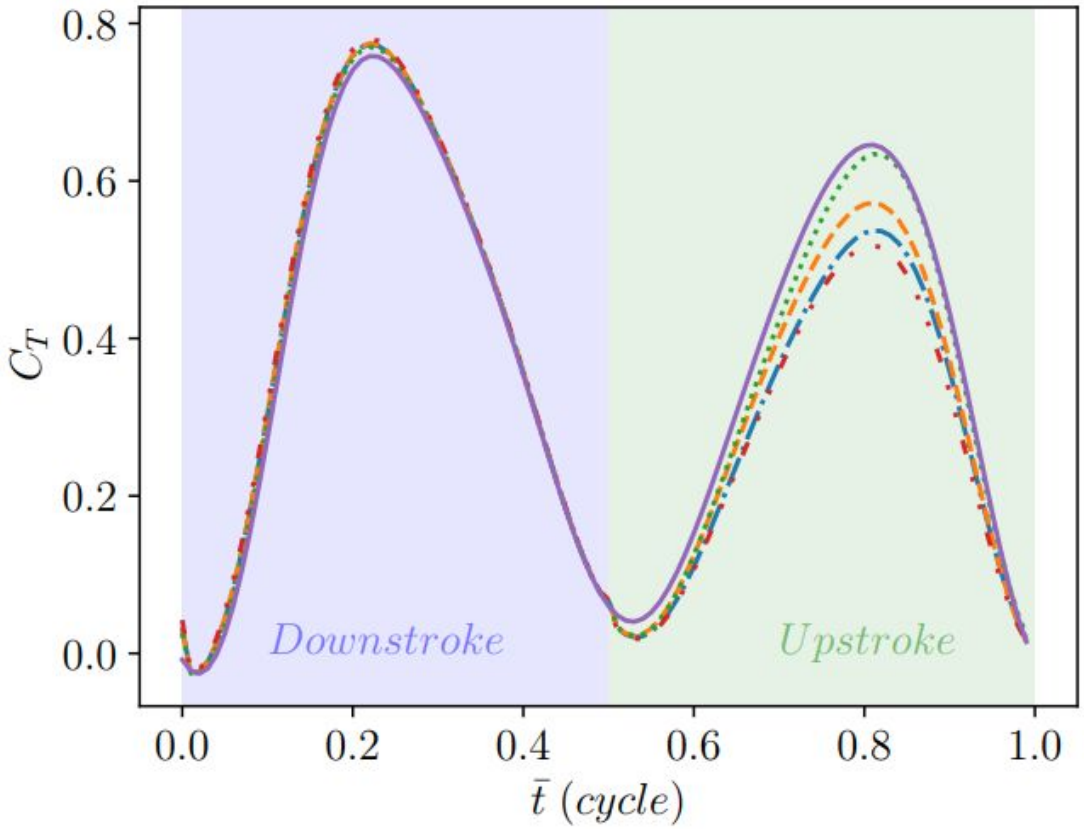
(b) Pitch



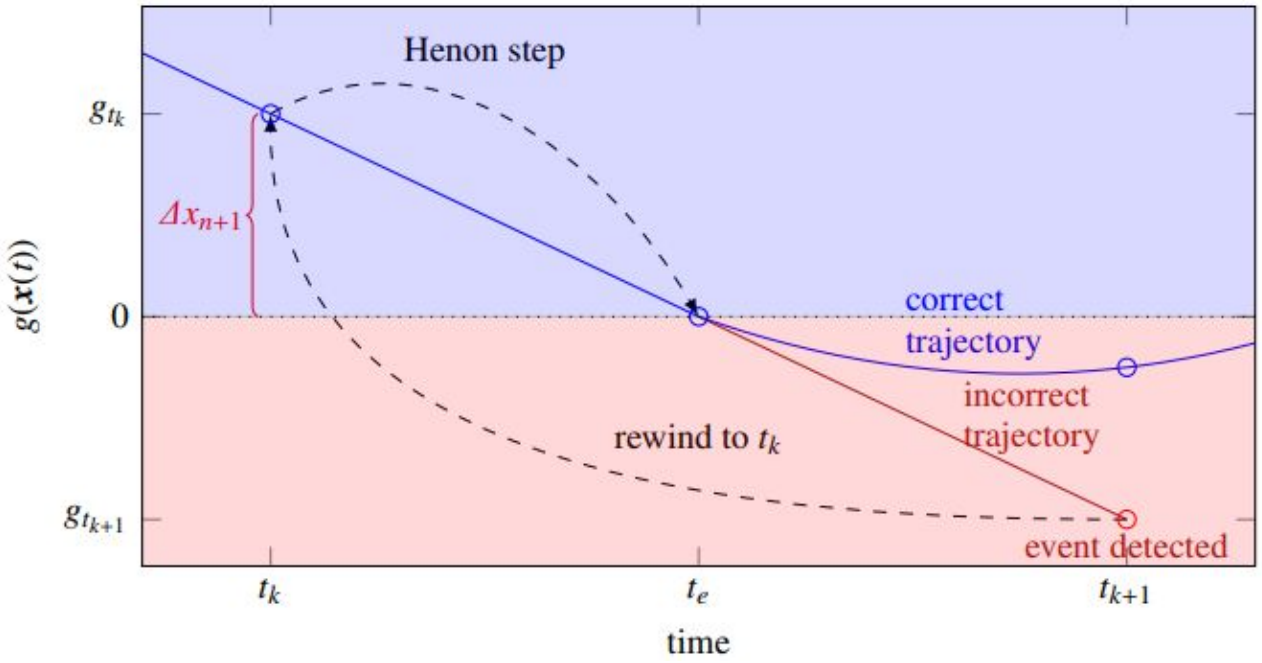
(c) Heave

Aerodynamics

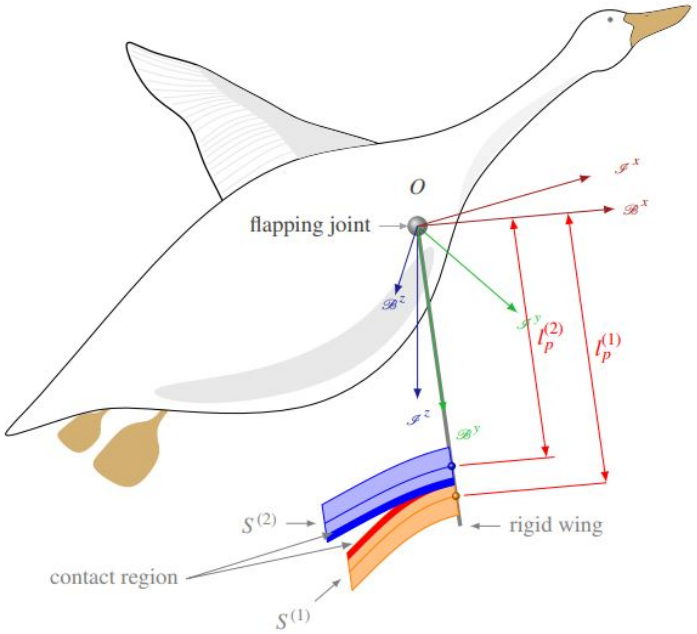




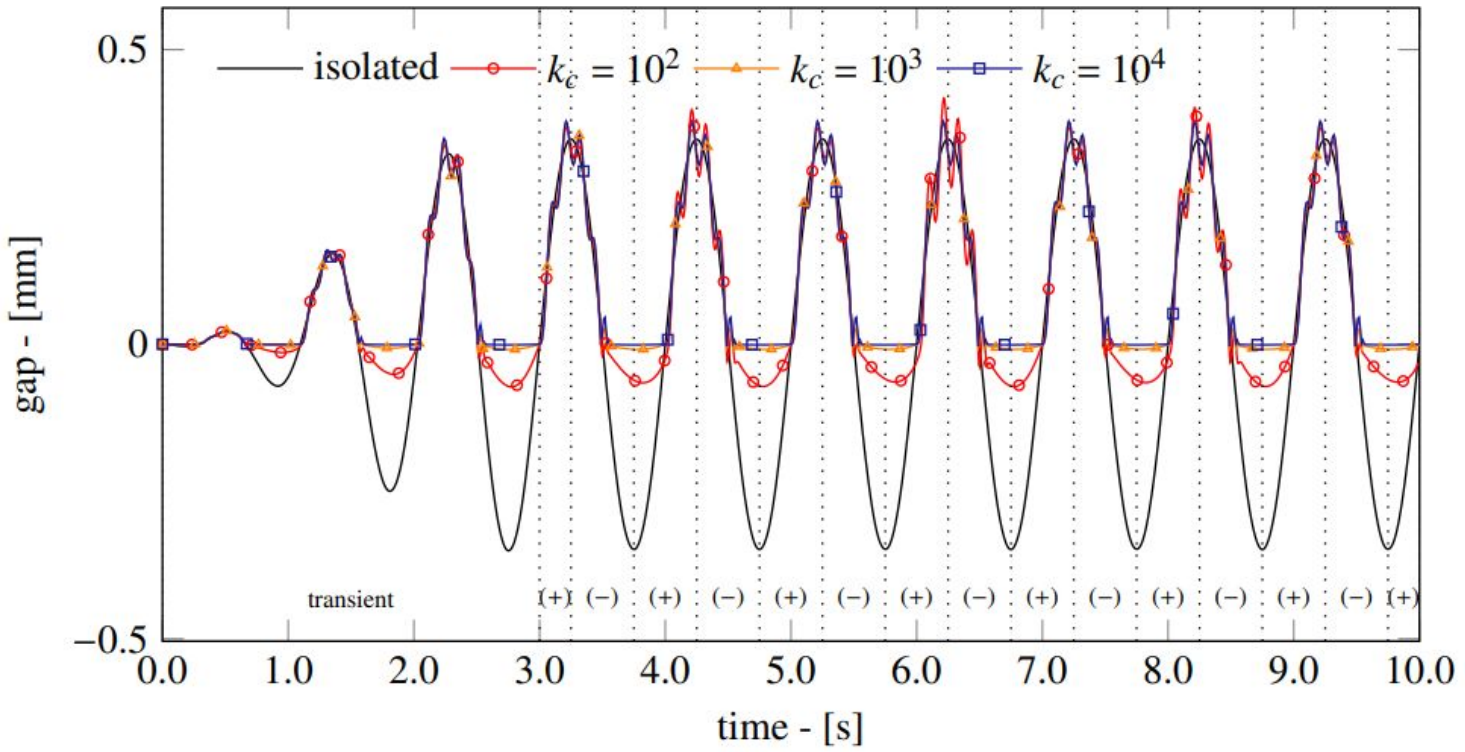
Aeroelastic modeling

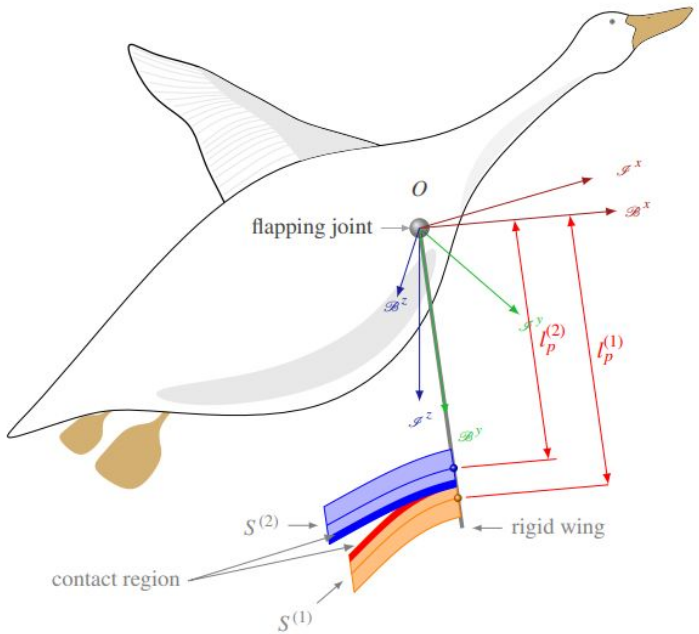


$$\begin{Bmatrix} \dfrac{dx}{dx_{n+1}} \\ \dfrac{dt}{dx_{n+1}} \end{Bmatrix} = \begin{Bmatrix} \dfrac{f(x)}{f_{n+1}} \\ \dfrac{1}{f_{n+1}} \end{Bmatrix}$$

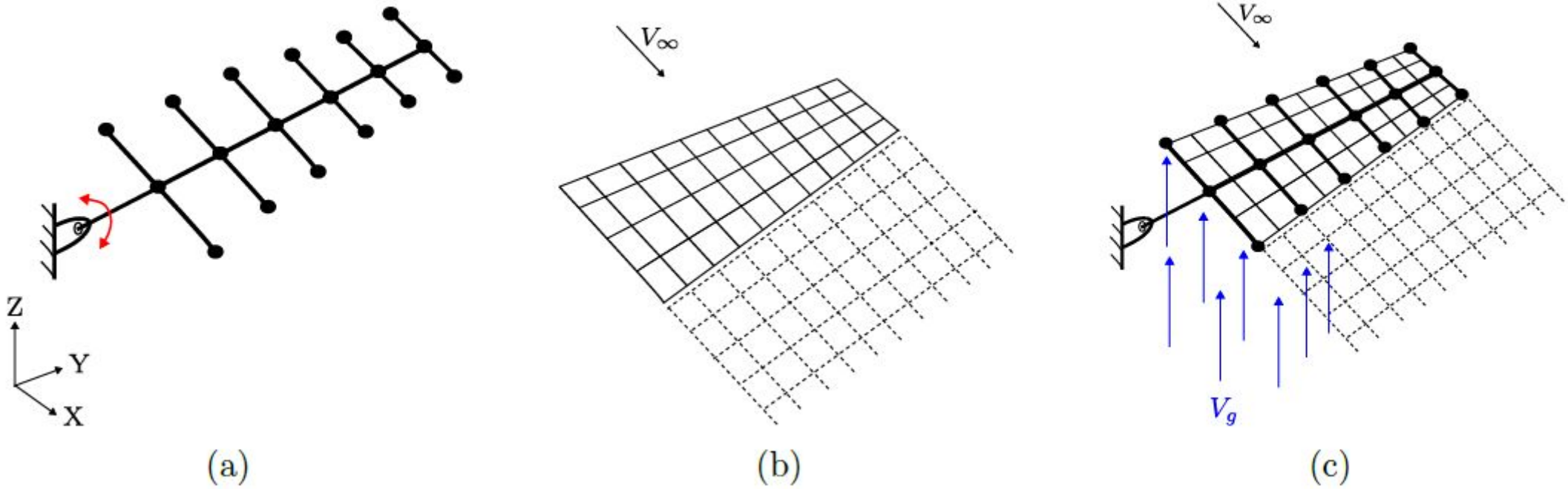


Aeroelastic modeling



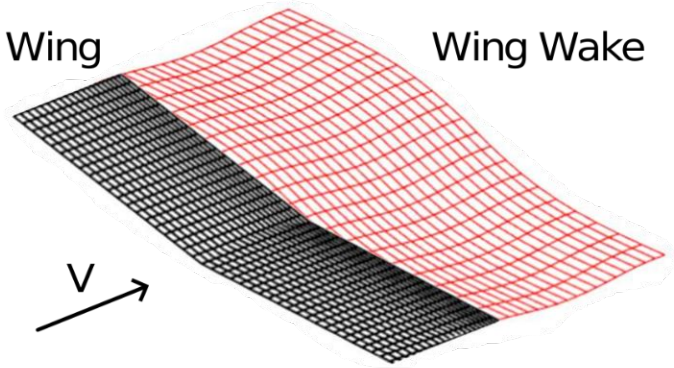


Aeroelastic modeling

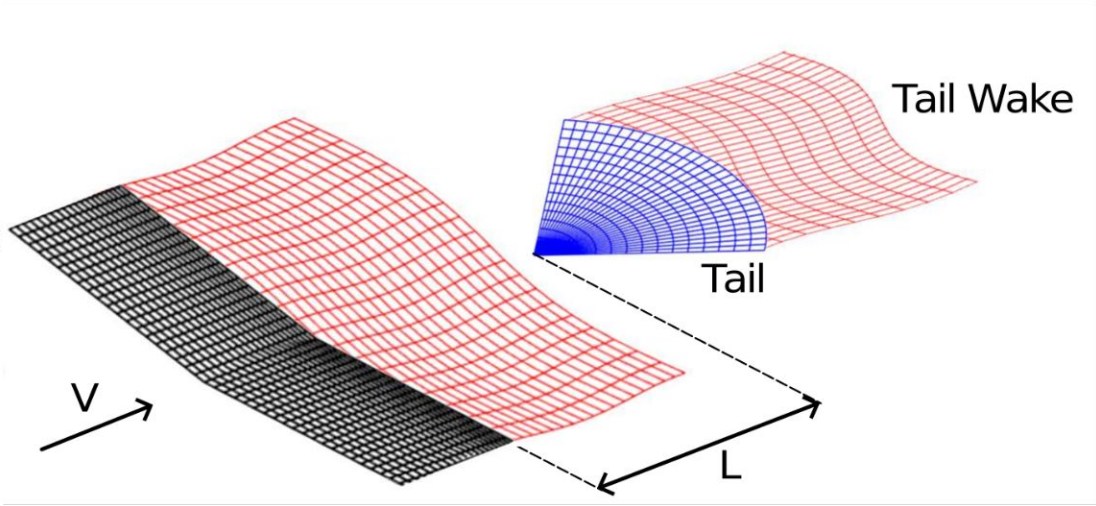


(a) (b) (c)

Aeroelastic modeling

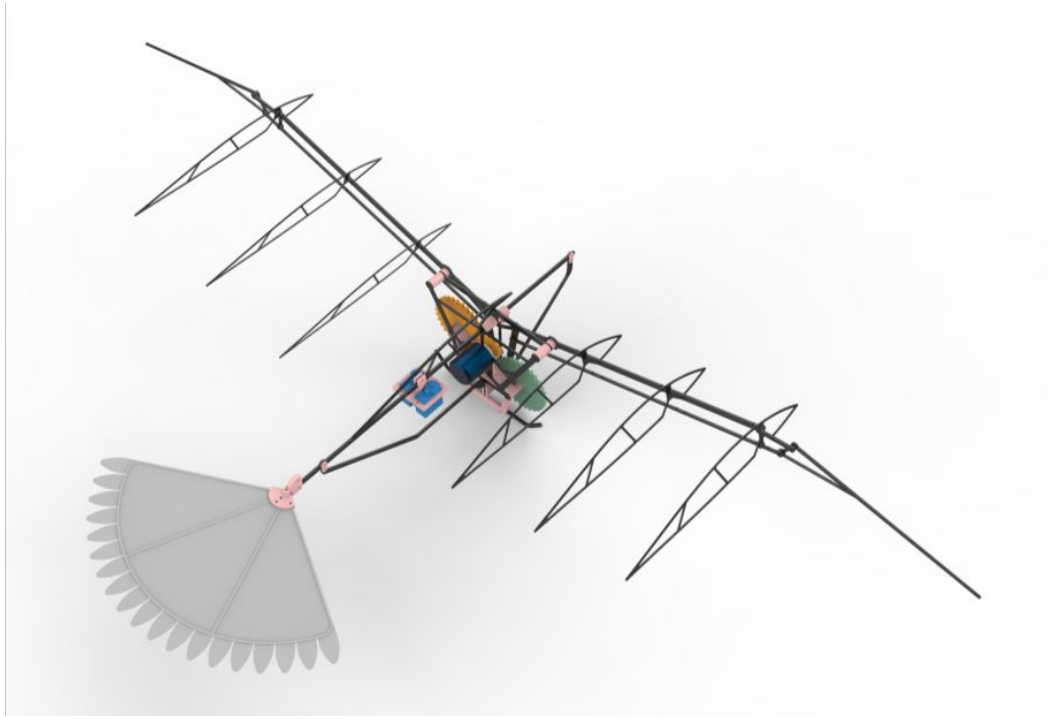


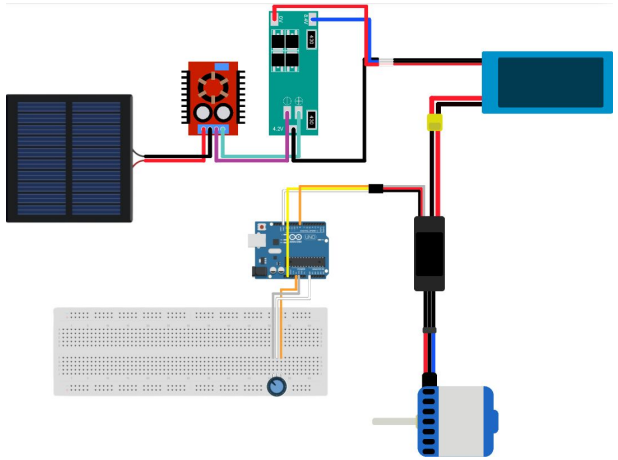
(a)

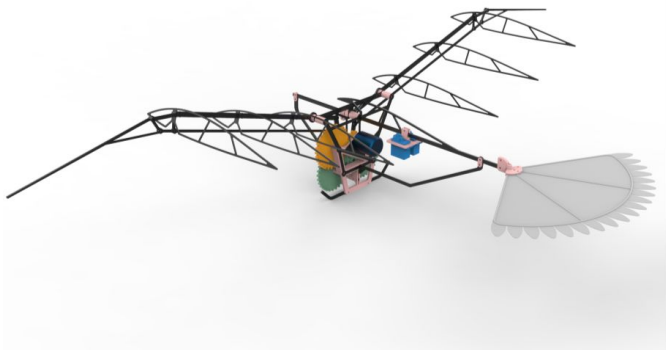


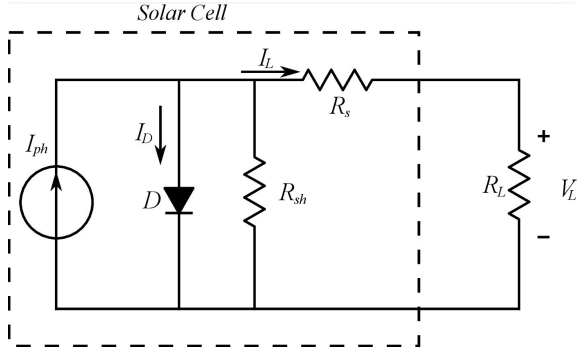
(b)

Design and Construction









Crack detection







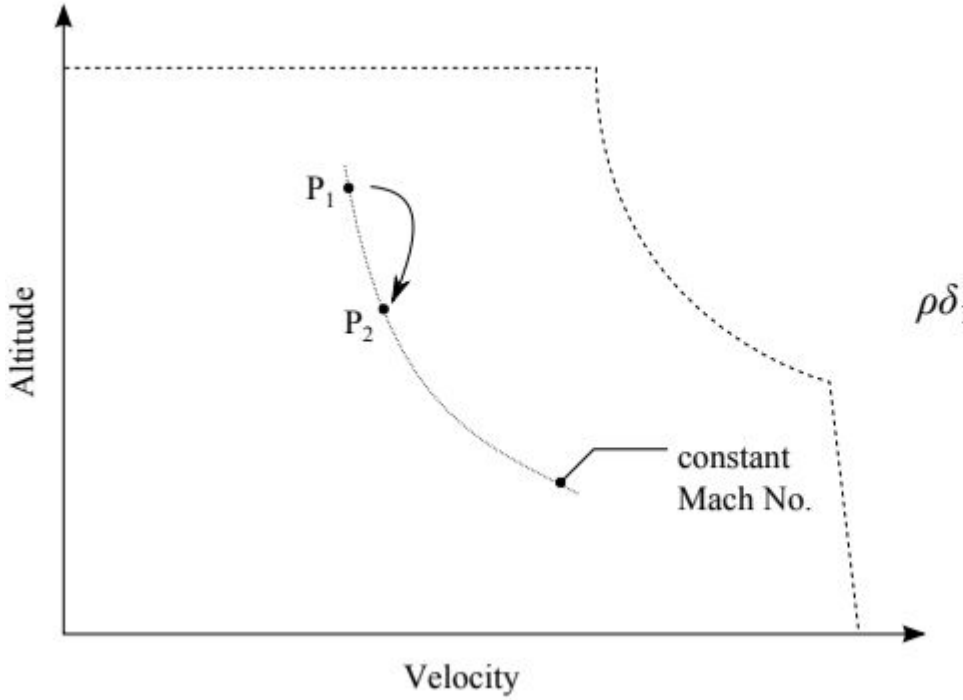


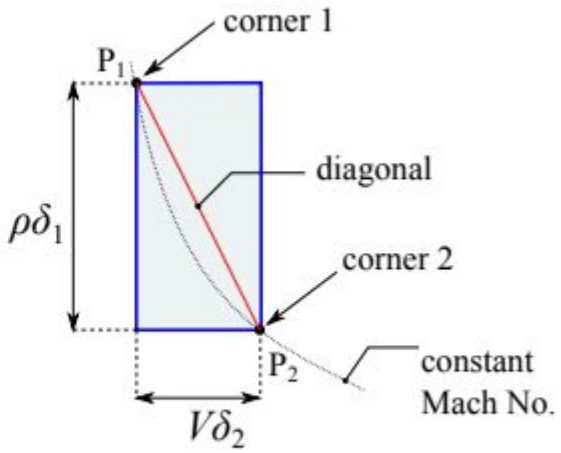


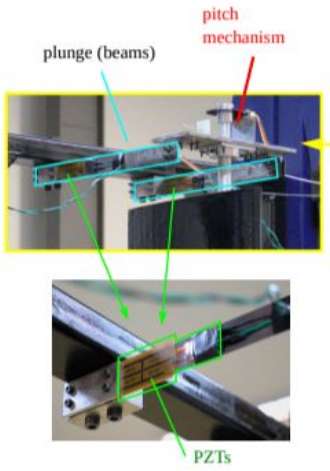


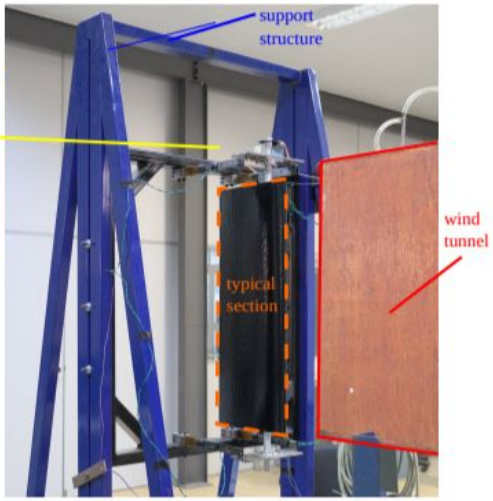
Accuracy:
> 90%

Flutter suppression



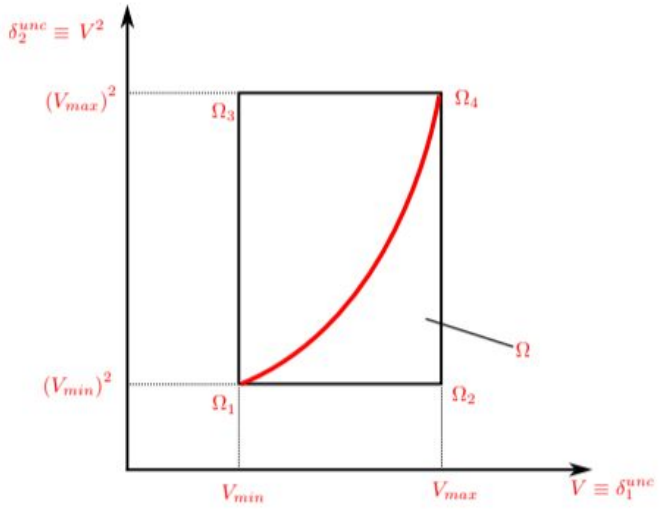






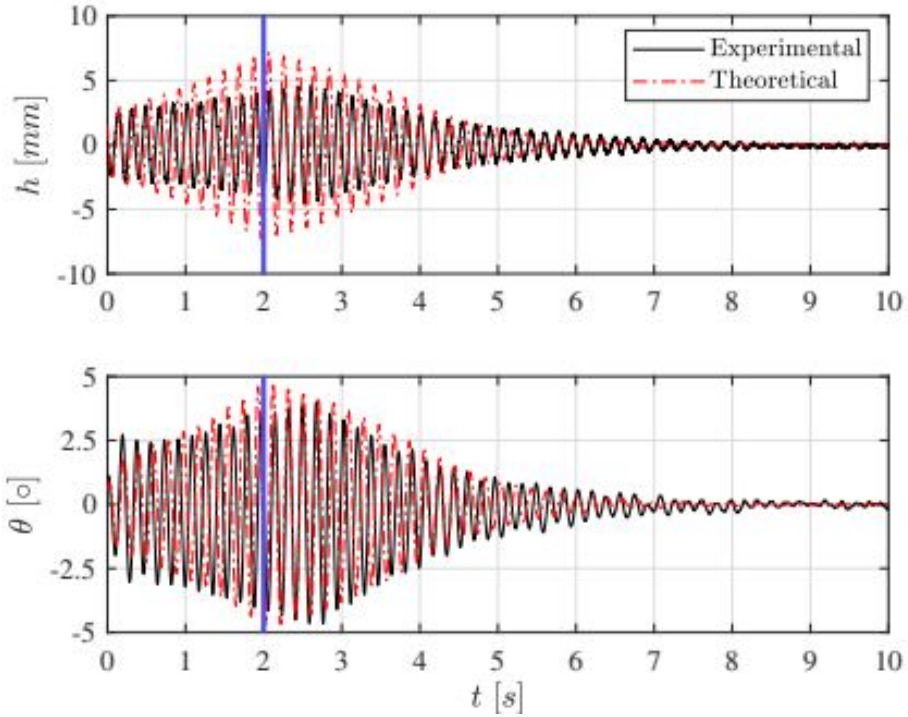
Flutter suppression

$$\mathbf{A}(V) = \mathbf{A}_0 + V\mathbf{A}_1 + V^2\mathbf{A}_2$$

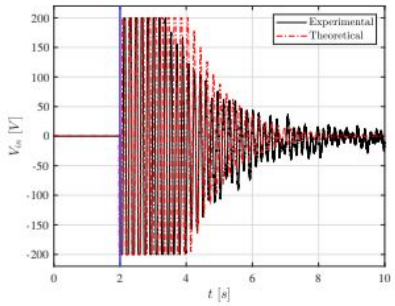


$$V_{unc} = V_n(1 + \delta_1^{unc})$$

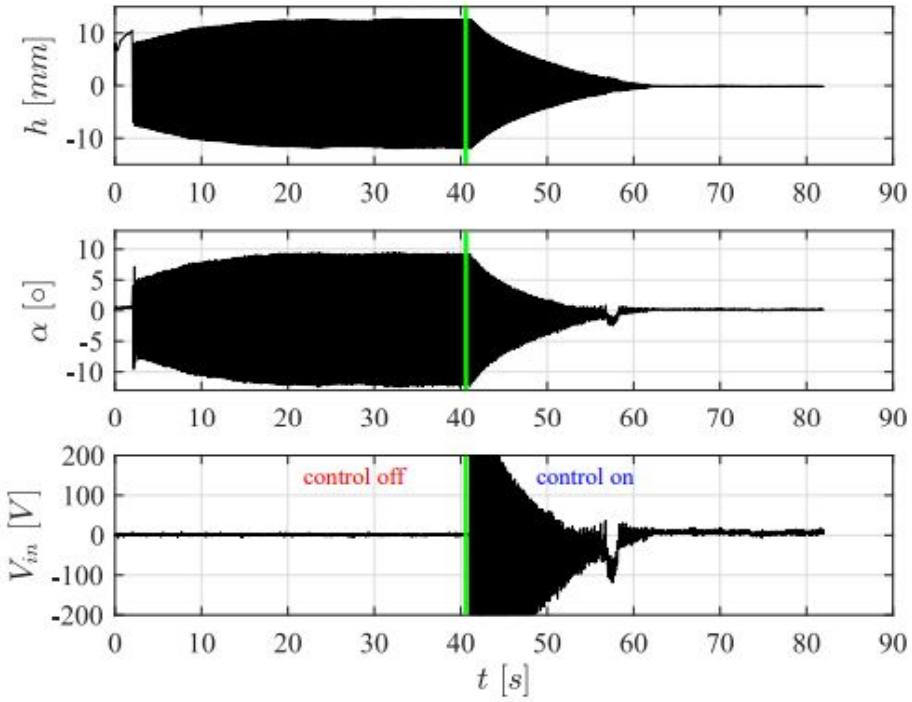
$$V_{unc}^2 = V_n^2(1 + \delta_2^{unc})$$

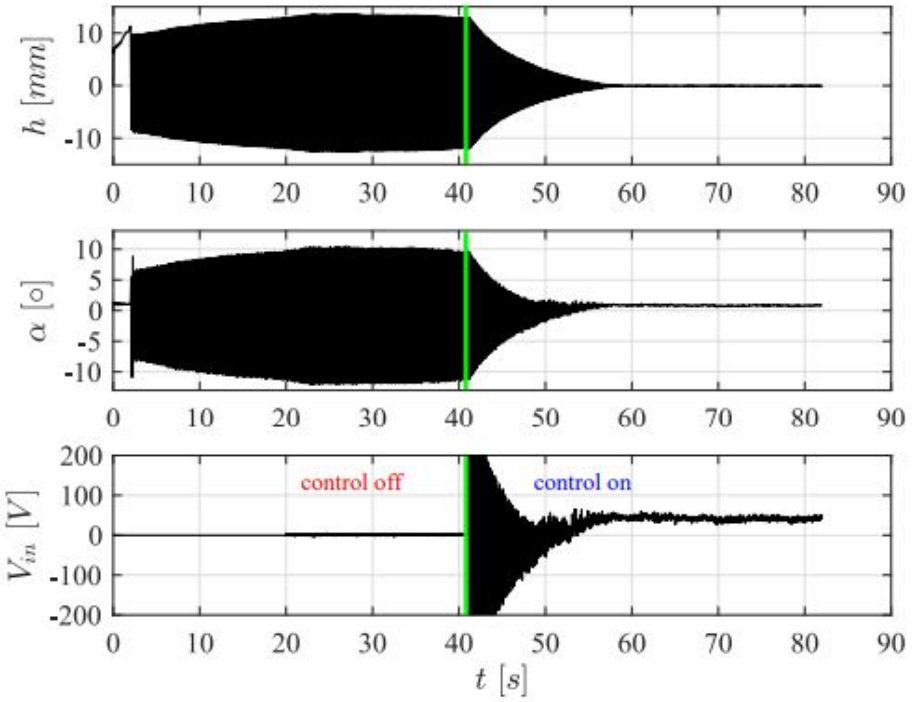


$$\mathbf{A}(V_{unc}) = \mathbf{A}_n + \delta_1^{unc}\mathbf{A}_1 + \delta_2^{unc}\mathbf{A}_2$$



Flutter suppression - LCO





Acknowledgment

FAPESP

FAPESP France Week 2025

