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Stability of Flapping-of-Wings Flight of Butterfly

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Background & Objective

Butterflies can maintain desired flapping-of-wings flights stably against disturbances, e.g. gust, because of their adaptation-capability, even though they seem just repeat rhythmical and periodic motions. What are the veiled mechanisms to stabilize the flapping-of-wings flights?

We would like to clarify effects to stabilize the flights focusing on flowfield generated by the flapping-of-wings motions.

Approach

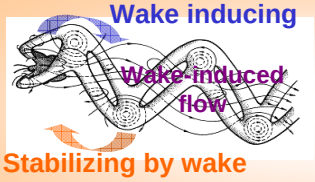
1. Experiments
- motion measurement using cameras
- aerodynamic forces
- airflow visualization

2. Mathematical model
- rigid multibody system
- unsteady flow

3. Stability analysis using mathematical model
- joint trajectory search for periodic flapping-of-wings flight
- perturbation analysis for trajectory stability
- comparison with and without free-vortices

periodic flapping-of-wings flight: same trajectory of entire motion is repeated every flapping period

Result

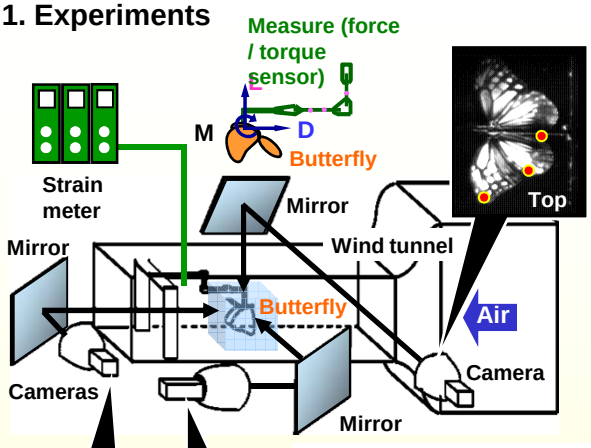


Stabilizing by wake

Butterfly flies making the unsteady wake-induced flow (free-vortices)!
Flapping-of-wings flight is stabilized by the wake-induced flow (free-vortices)!

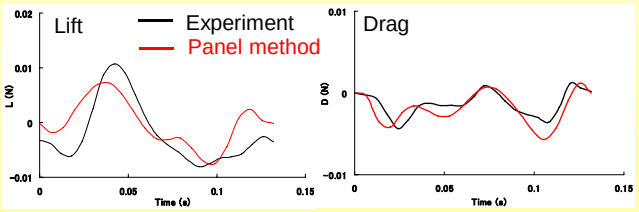
Senda, et al., "Stabilization of Flapping-of-Wings Flight of a Butterfly, Considering Wakes," in Bio-mechanisms of Swimming and Flying - ISABMEC2006-, Springer, Tokyo, 2007. (in press)

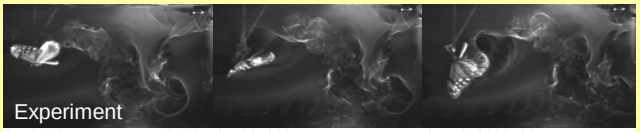
1. Experiments

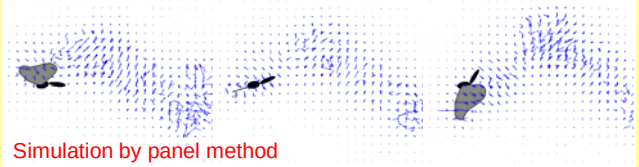


2. Mathematical model

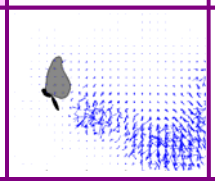
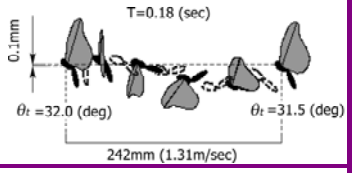
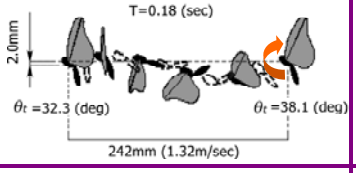
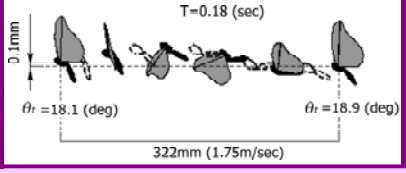
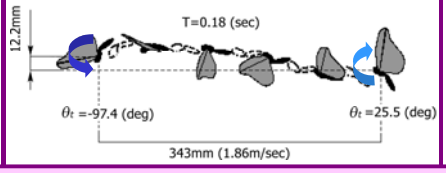
Mathematical model in good agreement with measured data
multibody dynamics using Lagrangian equations
＋aerodynamics using panel method







3. Stability analysis using mathematical model

	flowfield	almost periodic flight	Flight with initial perturbation	stability
(a) with wakes				rather stable
(b) without wakes				unstable