On flapping flight in turbulence

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More information: http://aefit.cfd.tu-berlin.de/

Results

Free-flight in turbulence (6 DoF, ongoing work)

The numerical method is based on the volume penalization method and a Fourier discretization. All scales are resolved on a fine grid. The FluSi code is open-source and freely available. All computations are done on massively parallel machines.

Key parameters:
- \( R = 13.2 \) mm
- \( \omega = 2.5 \) m/s
- \( m = 177 \) mg
- \( \Lambda = 200 \) mg

Either fixed flight (3 DoF) or free-flight (6 DoF) without control

The roll direction is the most sensitive

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Influence of turbulence intensity on tethered flight

The influence of turbulent scales on tethered flight

Laminar inflow as reference simulation

Our main questions are:
1) How does turbulence affect flapping flyers?
2) Which scales of turbulent motion are most relevant?
3) Does turbulence destroy the leading edge vortex?

Fluctuations

Vertical force

Horizontal force

Influence of turbulence intensity on tethered flight

First we study the influence of turbulence intensity on a tethered insect. Based on the wake turbulence generated by the insect itself, we choose intensities between 16% and 99%, which contains the experimental range from [1].

The HIT simulations are precomputed and the velocity fields are saved. For each simulation, several uncorrelated fields are used for statistical ensemble averaging.

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Tu = 0.33

Tu = 0.17

Tu = 0.99

Vertical force

Horizontal force

Turbulence intensity

Ensemble-Average

0.5% confidence

0.25% confidence

Tu = 0.99

Tu = 0.66

Tu = 0.33

Tu = 0.17

Influence of turbulent scales on tethered flight

In the next step, we define different turbulence fields for the same turbulence intensity, to study what influence the different length scales have on the flyer. The turbulence intensity is fixed to 13% and by varying the forcing wavenumber in the HIT simulations, but the scales are altered.

Influence of turbulent scales on tethered flight

The fluctuations in forces and moments are very sensitive to changes in the integral length scale. If it is smaller than the wing length, the fluctuations decrease significantly, while the changes between 0.77 R and 1.54 R are smaller.

We conclude that it is rather the scale dependent energy which matters for the insect than simply the turbulent kinetic energy.