Passive flutter suppression using a nonlinear tuned vibration absorber

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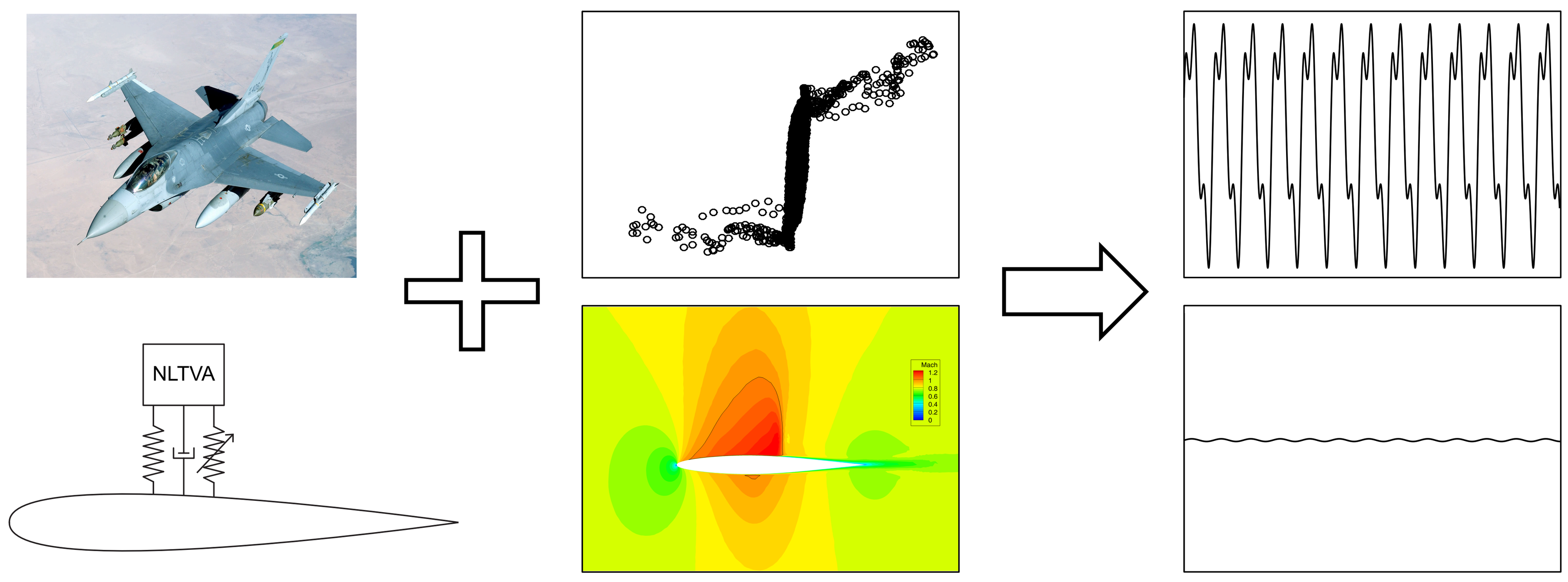
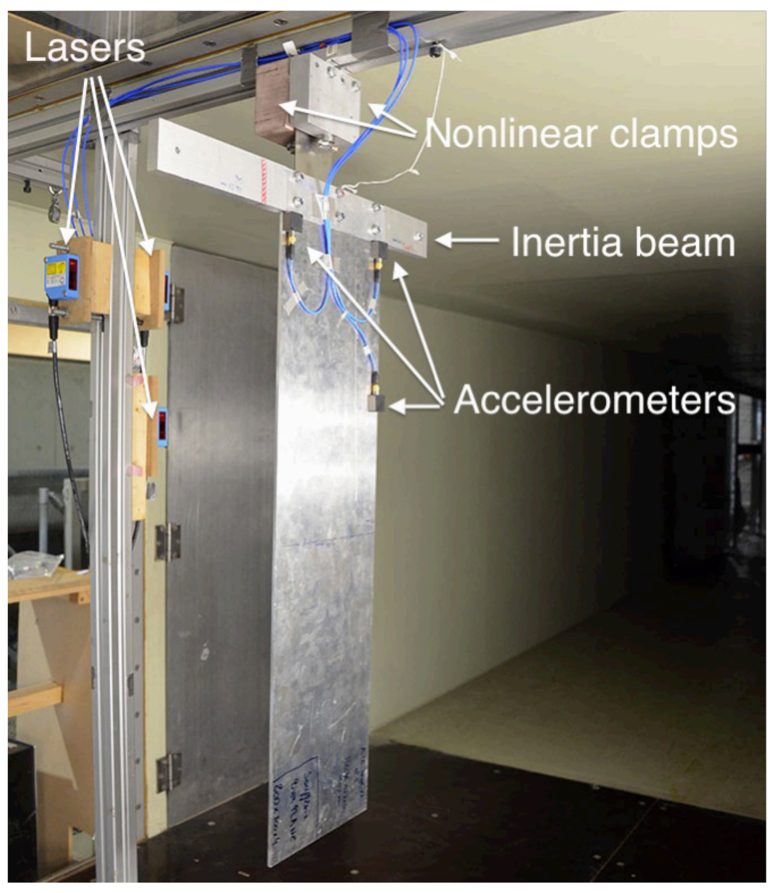
Vibration absorbers can suppress aeroelastic limit cycle oscillations



- Structural and aerodynamic nonlinearities in aircraft can cause aeroelastic limit cycle oscillations. Among them, transonic buzz, freeplay and bolted connections are the most common.
- A linear tuned vibration absorber (LTVA) or a nonlinear tuned vibration absorber (NLTVA) can mitigate or even suppress these oscillations.

Aeroelastic system and model

- Vertical flat plate with 2 rigid DOFs
  - pitch (structurally hardening)
  - flap (linear)
- Reduced order model
  - pitch and flap DOFs
  - linear Wagner aerodynamics
  - 2d flow
  - direct simulations using RK45
  - continuation using MATCONT



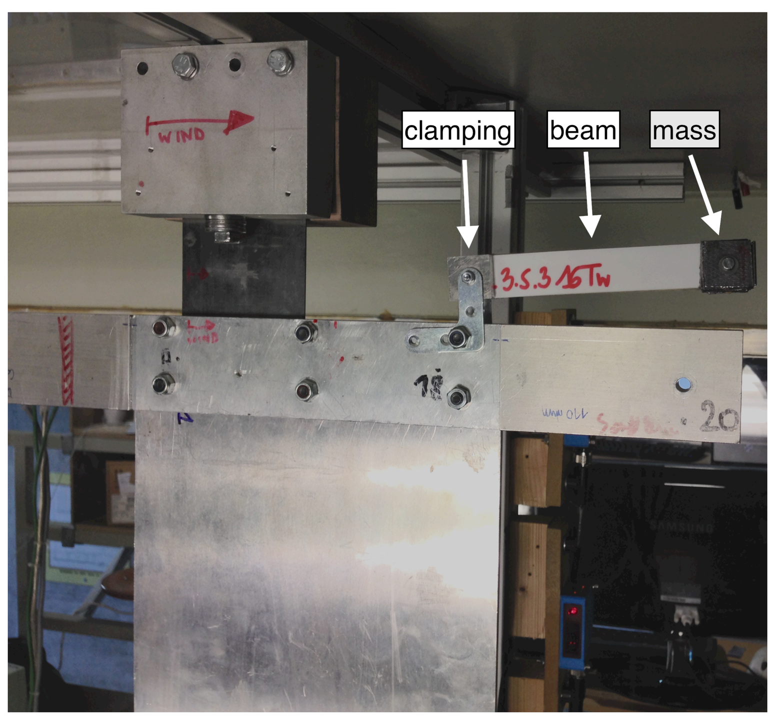
Absorber design

- Linear absorber (LTVA)

The LTVA is made of a mass of 62 to 70 grams attached at the end of a cantilever beam. Because low stiffness and high damping are required, the beam is made of a sandwich of PVC sheets and viscoelastic tape.

- Nonlinear absorber (NLTVA)

A NLTVA can easily be built using doubly clamped beam however it was not tested in the wind tunnel.



References

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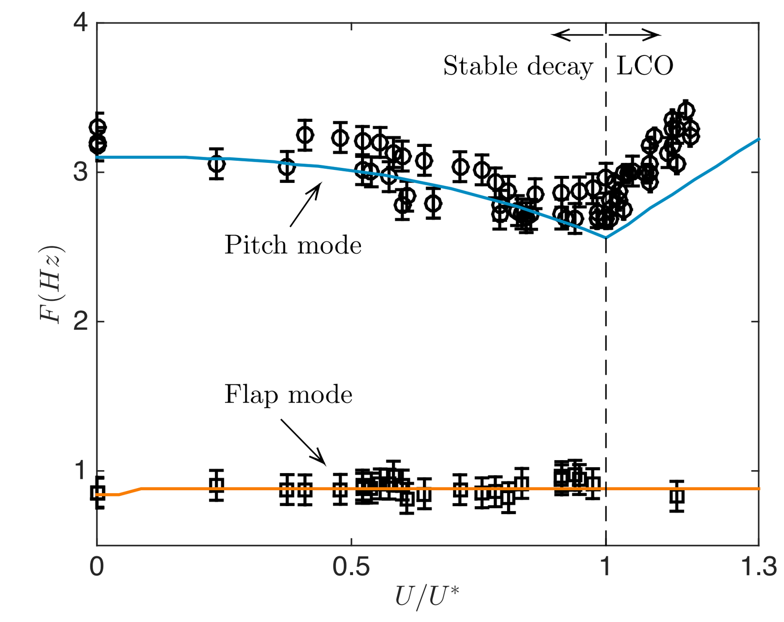
Aeroelastic analysis

- Frequency variation with airspeed

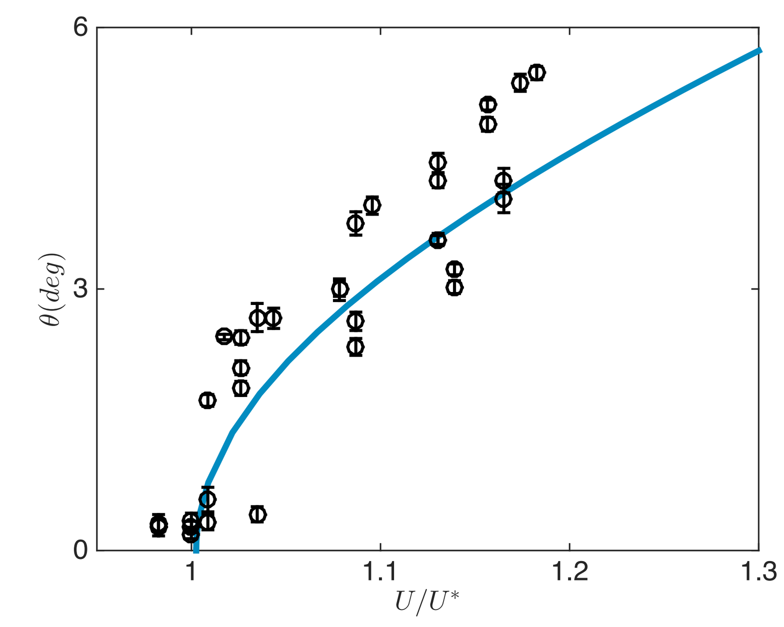
The system is tested in the wind tunnel and the results are compared to the model.

The model and the experiments show that the pitch frequency decreases until flutter occurs while the flap frequency appears to be stable. This frequency variation with airspeed is challenging because the absorber can only be tuned on a single frequency.



- Pitch bifurcation diagram

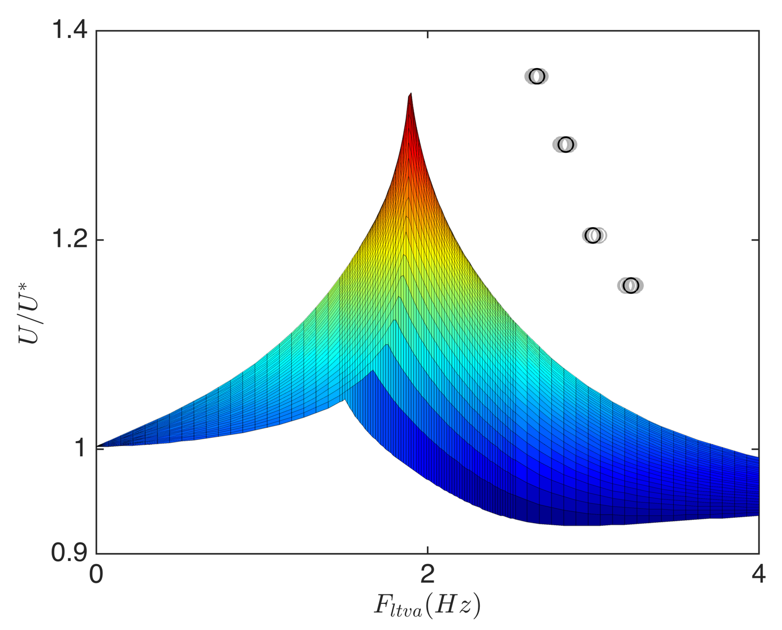
Above the flutter speed, limit cycle oscillations arise from a super-critical Hopf bifurcation. Their amplitude increases gently with the airspeed. Again, the model and the experiments agree very well with each other.



Absorber performance

- LTVA => increased flutter speed

The experiments and the model exhibit an improvement of 35% in flutter speed.

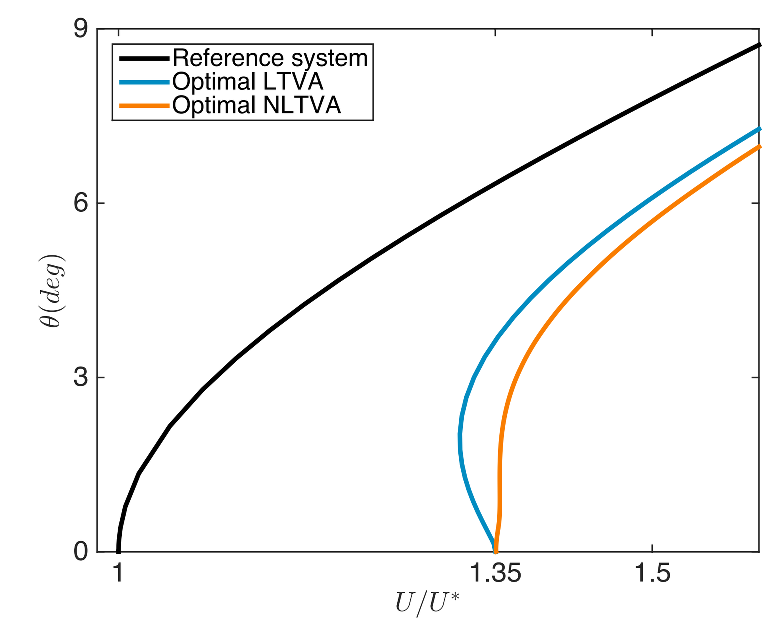


- LTVA => sub-critical bifurcation

Bifurcation analysis shows that according to the model, the LTVA leads to a sub-critical bifurcation because it is detuned at high enough pitch angles. No experimental data was gathered however because it was not possible to build absorbers with a stiffness low enough.

- NLTVA => super-criticality restored

The addition of the nonlinearity has no effect on the flutter speed however it restores the super-critically and delays the fold.



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