James Dilworth
Laura Rovira Crespo

Fluid Structure Interaction Simulation of Hood Flutter

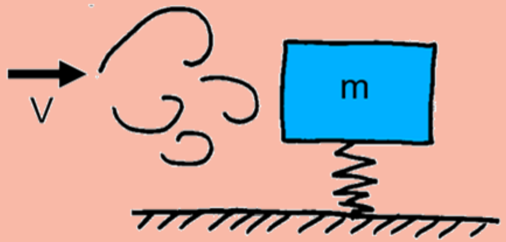
Outline

- Aeroelastic Phenomena
  - Extraneously Induced Excitation
  - Instability Induced Excitation
  - Movement Induced Excitation
- Hood Flutter Study
- Hood Flutter FSI Analysis – Outline
  - Pressure profile on DrivAer model
  - Time-varying loads from wake of preceding vehicle
  - FSI of spoiler
  - 2D FSI of flexible hood
- Conclusions

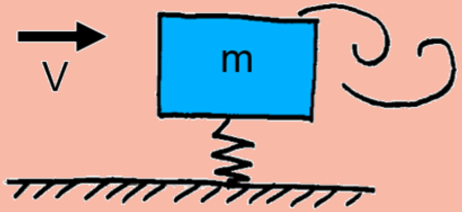
Aeroelastic Phenomena

3 groupings for aeroelastic phenomena from Naudascher & Rockwell:

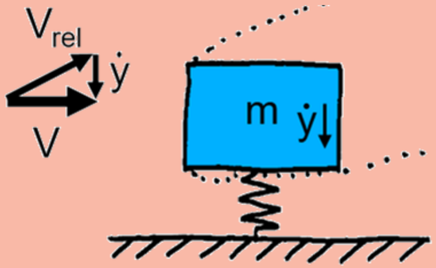
1. **Extraneously Induced Excitation**



2. **Instability Induced Excitation**



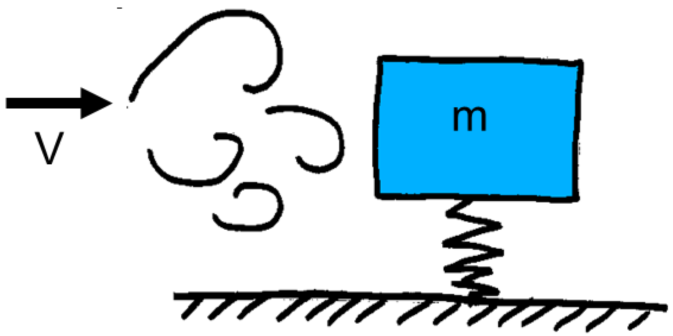
3. **Movement Induced Excitation**



Aeroelastic Phenomena

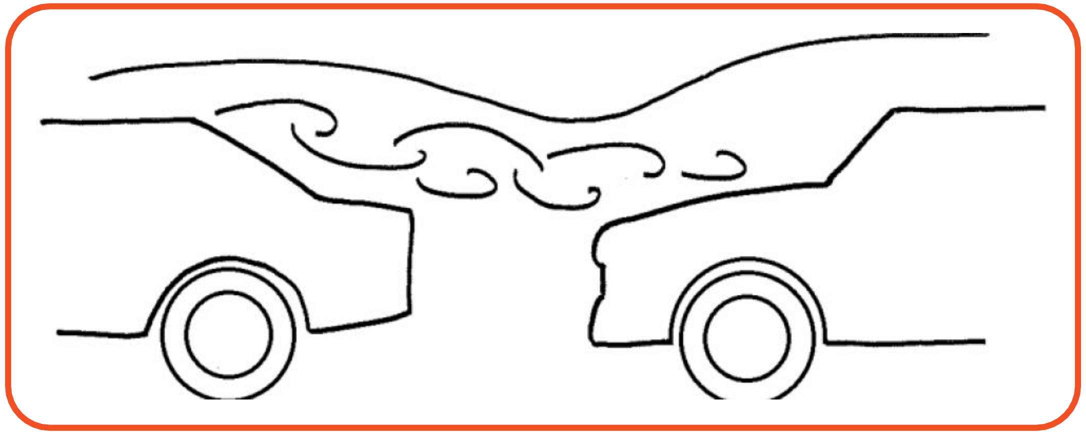
1. Extraneously Induced Excitation

Excitation caused by fluctuations in the oncoming flow conditions.



Examples:

- Buffeting
- Vortex shedding from upstream body



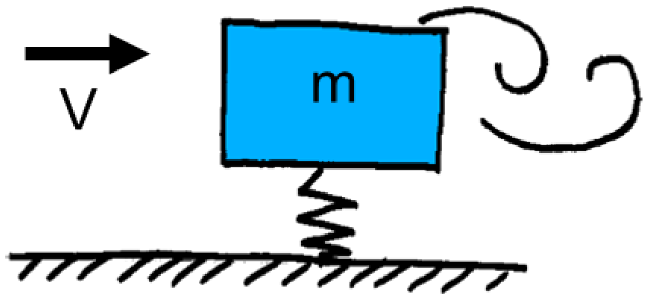
Aeroelastic Phenomena

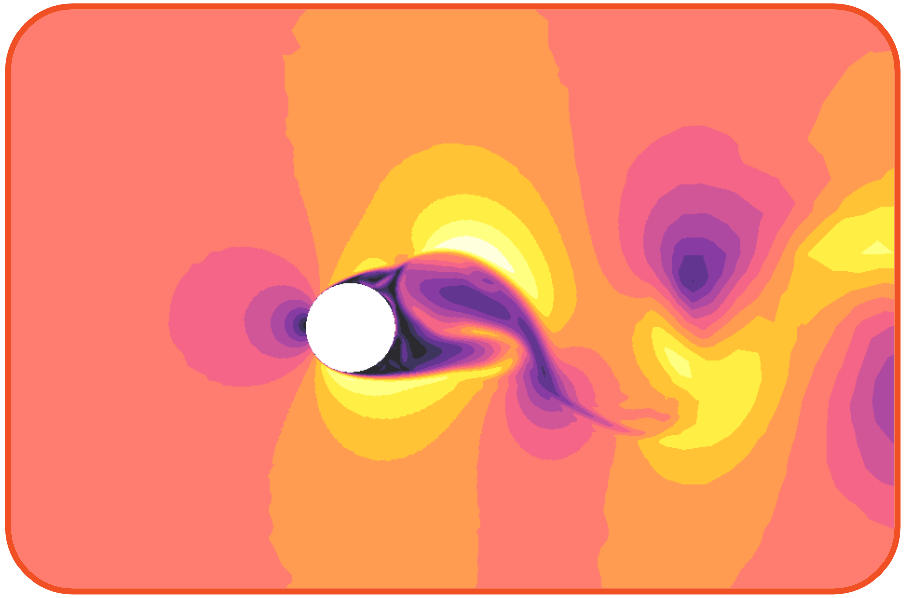
2. Instability Induced Excitation

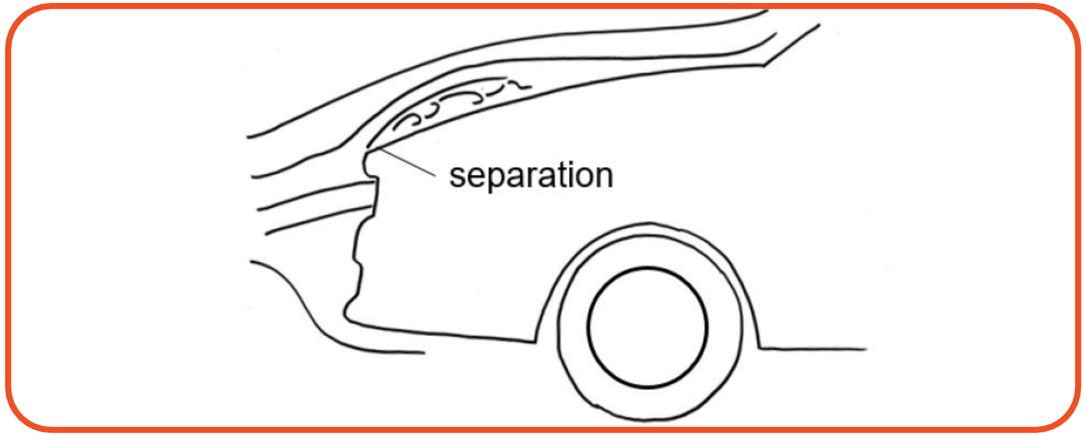
Excitation caused by flow instability about the structure.

Examples:

- Vortex shedding
- Separation







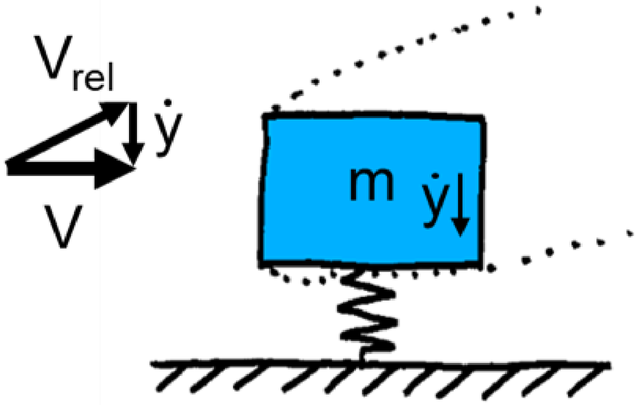
Aeroelastic Phenomena

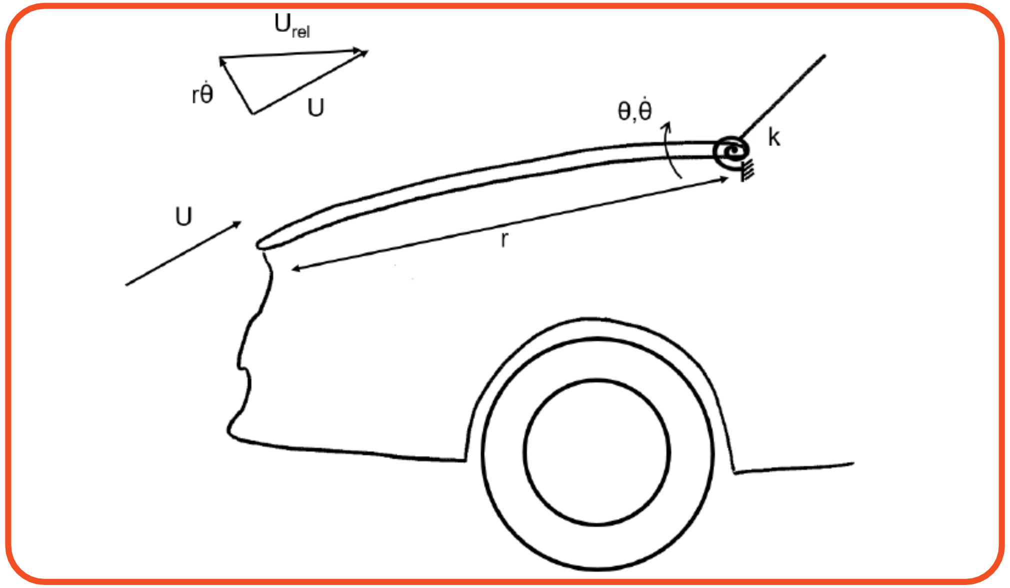
3. Movement Induced Excitation

Excitation caused by fluid forces arising from movements of structure.

Examples:

- Classical flutter
- Gallop





Hood Flutter Study

If we want to minimise the risk of hood flutter during design, what tools are there to analyse this problem?

- **One way coupled CFD and FEA – Apply pressure time histories from CFD to FEA model**
- **Fully coupled FSI simulations**
- **Aeroelastic wind tunnel tests**
- **Track testing**

Requirements: What do we need from FSI simulations to make them useful for bonnet flutter analysis?

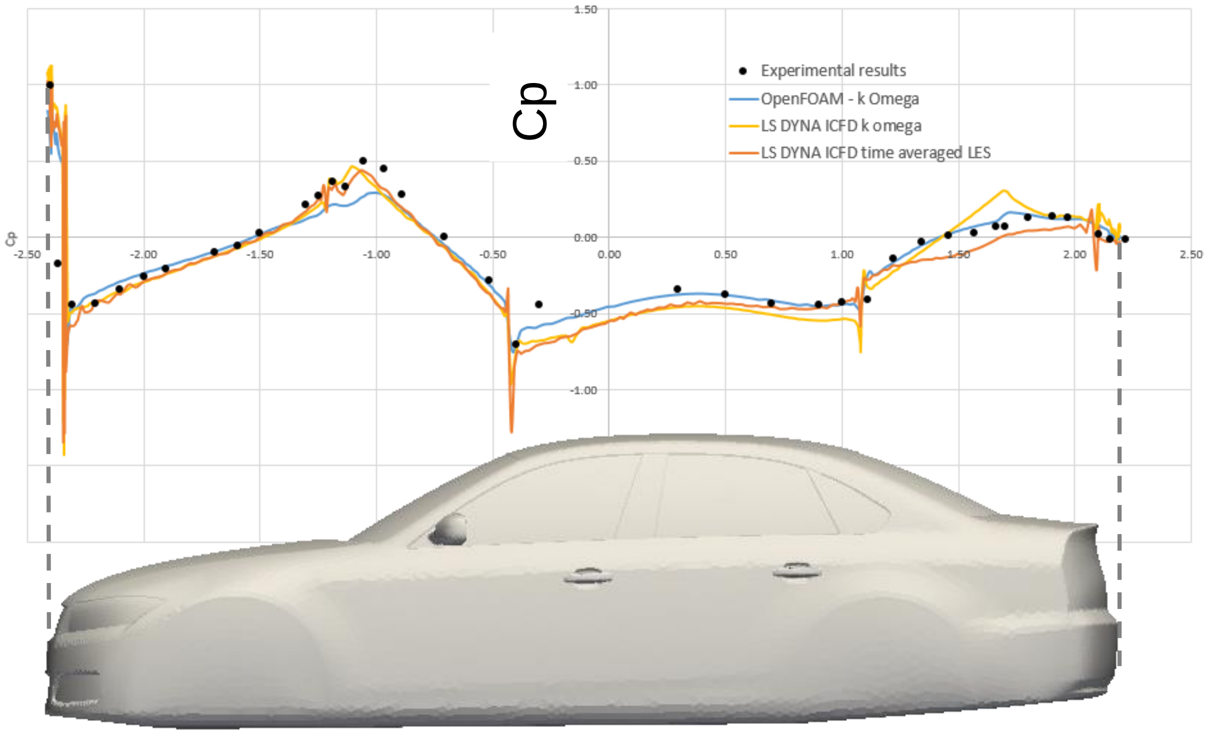
- <u>Accurate representation of Physics</u>
  - Strong, two way Coupling
  - High fidelity CFD
  - Bonnet gap opening
  - Engine bay flows
  - Opening mechanism
- <u>Scalability</u>

Hood Flutter FSI Analysis - Outline

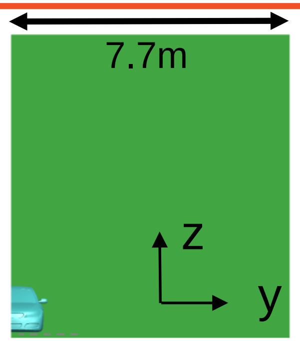
1. Validation of ICFD solver using DrivAer generic car model
2. Simulation of unsteady loads from the wake of a preceding car
3. FSI simulations of a spoiler on the DrivAer car
4. 2D FSI simulations of separated flow over a flexible hood

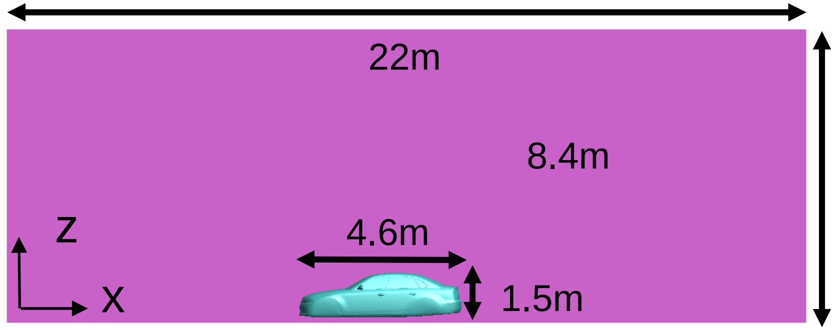
Pressure profile on DrivAer model

- Comparison is made to experimental pressure profile from TUM.
- Two ICFD simulations:
  - Steady state k-ω
  - Transient LES
- Steady state OpenFOAM k-ω simulation for comparison.
- Flow is sensitive to turbulence model.

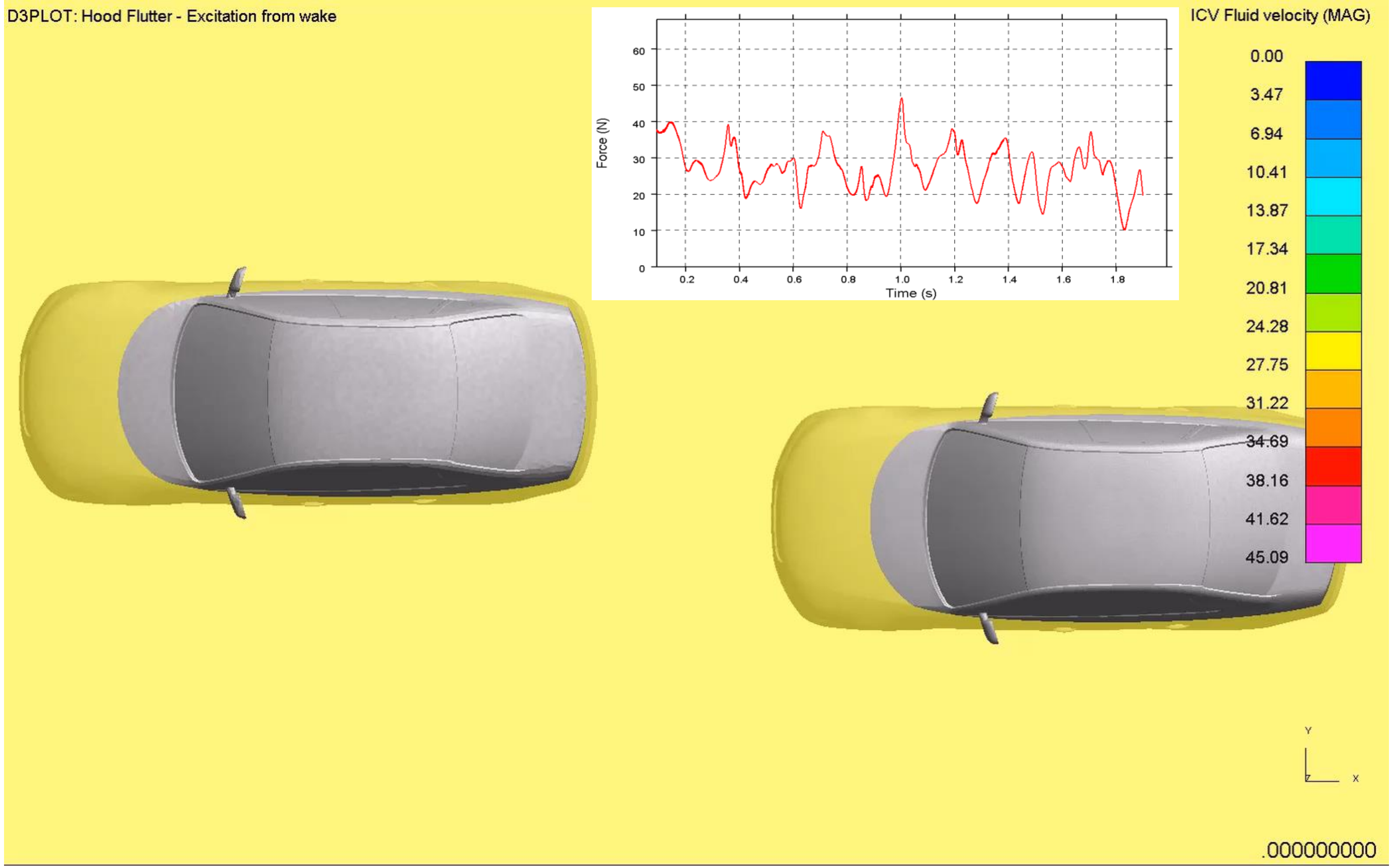


Computational Domain



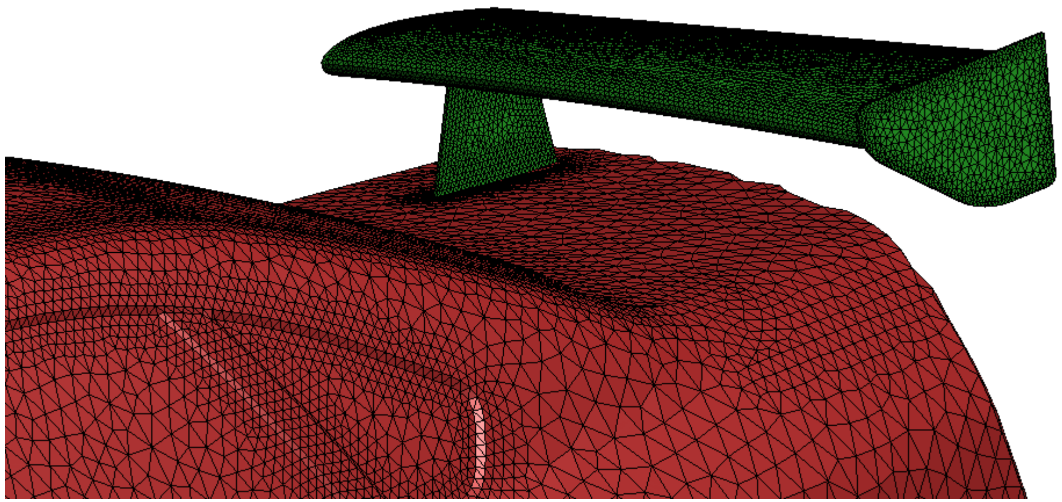


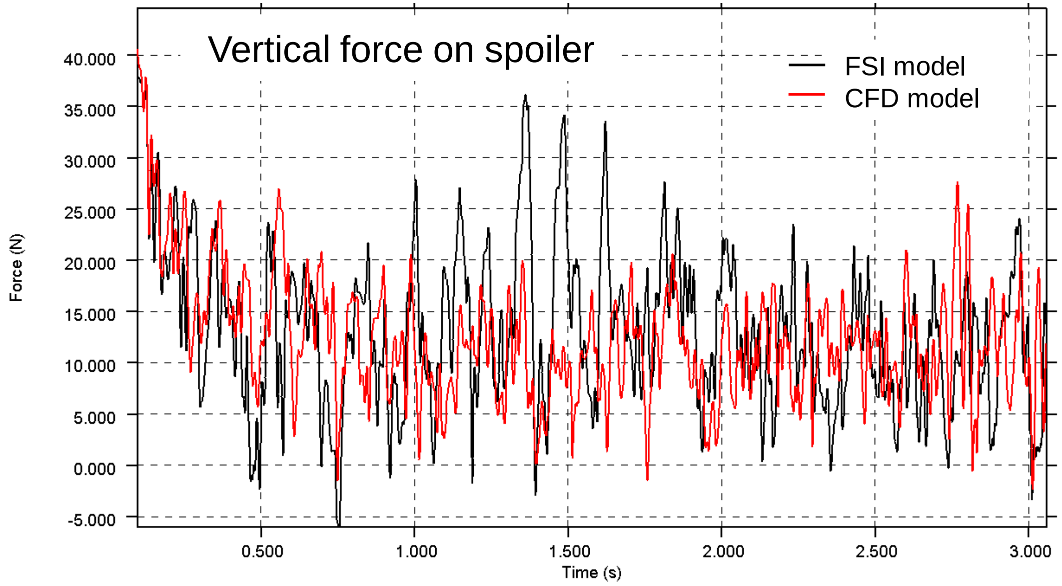
Time-varying loads from wake of preceding vehicle

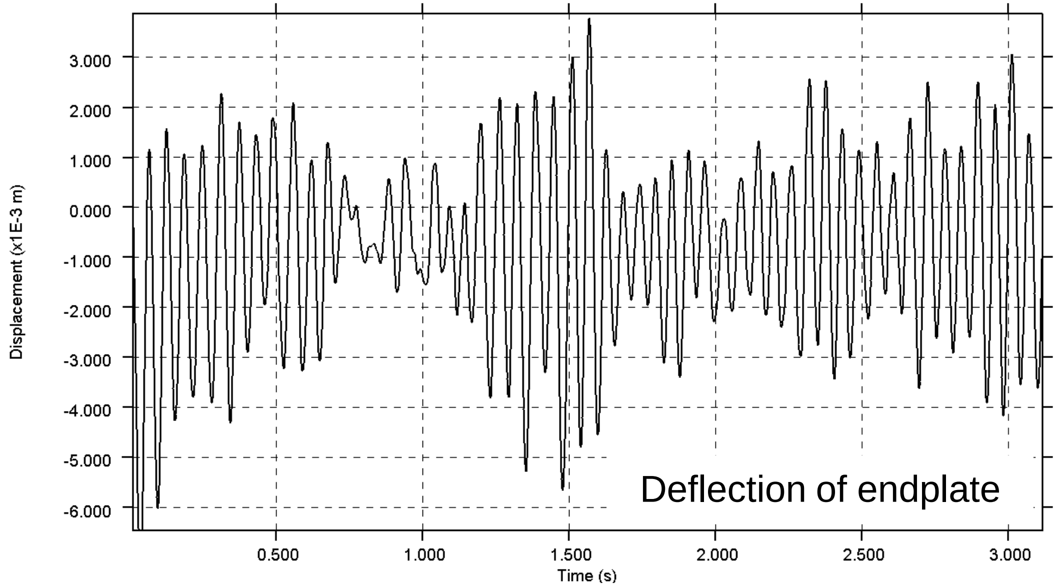


FSI of spoiler

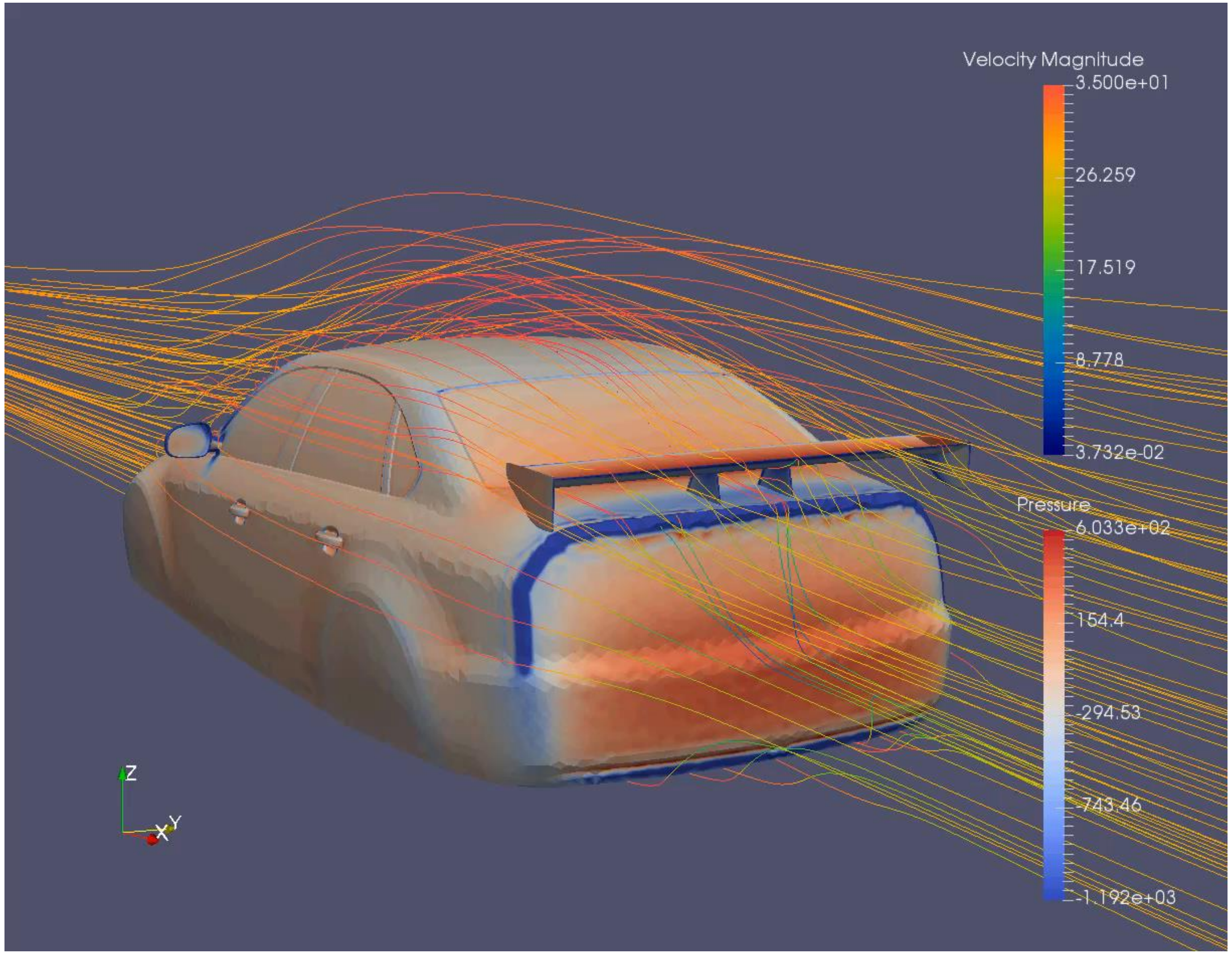
- Structural model of plastic spoiler added.
- Some difference in vertical loads, but load fluctuates due to eddies from rear window.
- Endplate of the spoiler visibly deflects.





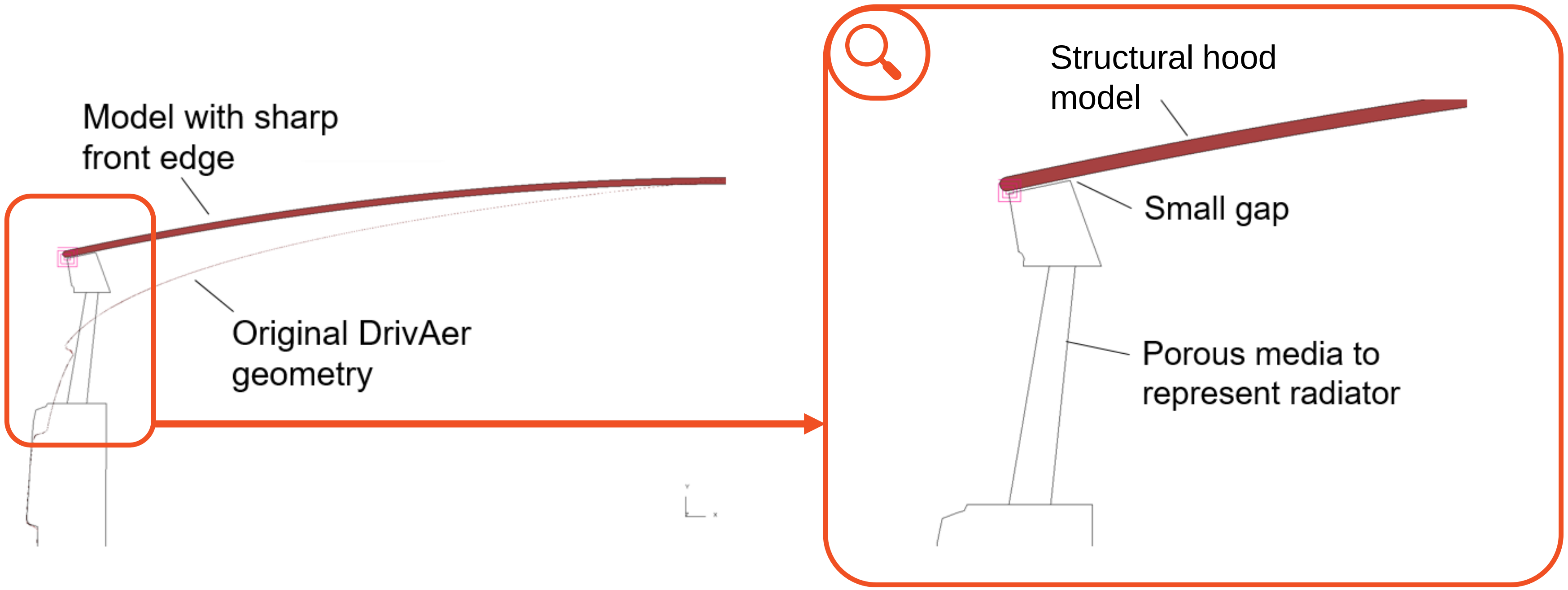


FSI of spoiler

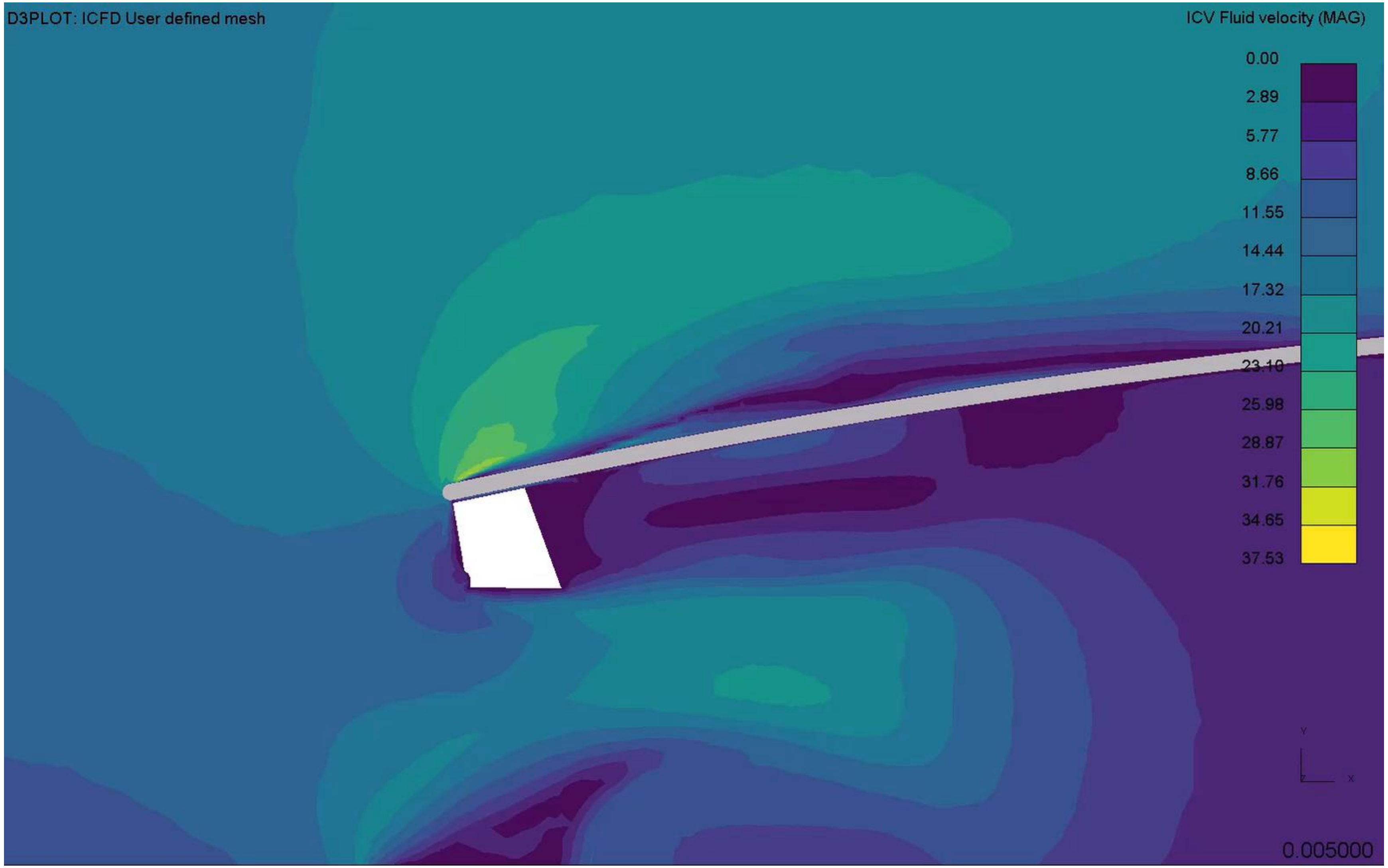


2D FSI of flexible hood

- Hood leading edge raised to promote separation.
- Thin gap under hood can open up.
- Non-linear spring on front edge to act as contact.



2D FSI of flexible hood



Conclusions

Conclusions:

- Validation of pressure profile around generic car geometry.
- Reproduction of structure excitations generated by the wake of a preceding vehicle.
- Model instability induced vibrations using the FSI tools.

Challenges:

- Complex models, long run times.
- Instability issues associated with remeshing.
- Validation required with results from aero-elastic wind tunnel testing.

ARUP