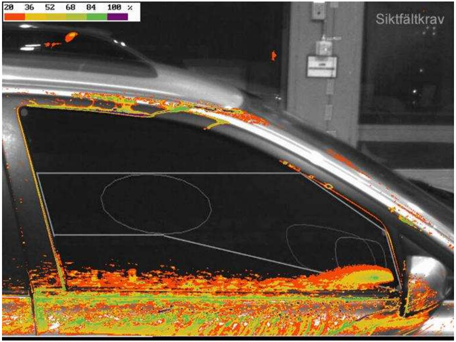
How to carry out fundamental research together with industry

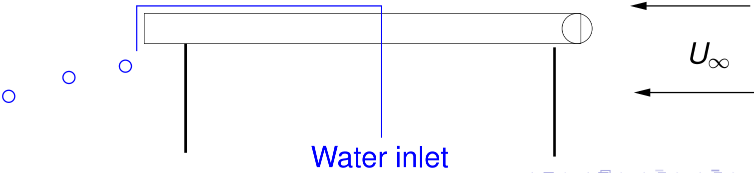
Lars Davidson
Division of Fluid Dynamics
Dept. of Mechanics and Maritime Sciences (M2)
Chalmers

APPLIED AND FUNDAMENTAL RESEARCH

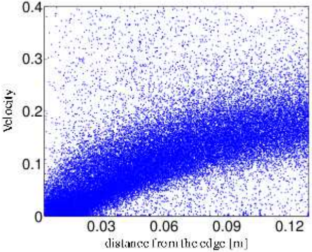
- I will show five nice examples of fundamental research carried out together with industry
  - Water droplets/ruvulets on side mirrors
  - Heat transfer in engines: exp & simulation
  - External windnoise disturbing driver and passengers (automotive)
  - Using active flow control for reducing drag on vehicles
  - Heat transfer in engines: development of simulation method

WATER: VOLVO CARS, FFI PROJECT, 2006-2011

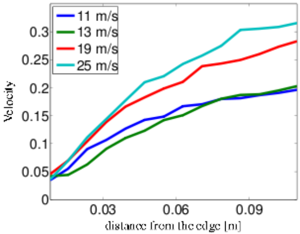




WATER: EXPERIMENT



(A) Scatter plot. Air velocity $V_{air} = 13$

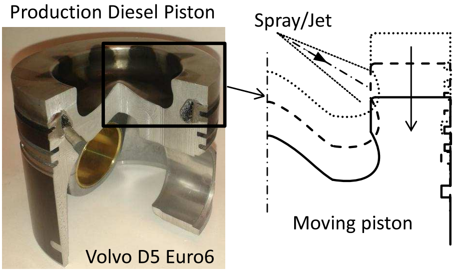


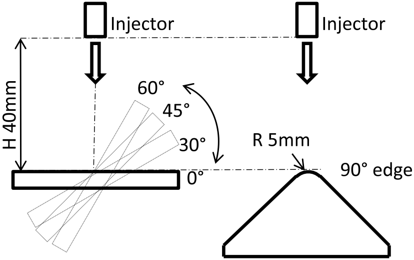
(B) Different air velocities.

FIGURE: Velocity of waterdrops that left the table.

$$\frac{\rho_\ell h_c V_{air}}{\sigma} = -155 + 280 V_{air}$$

T. Tivert and L. Davidson Experimental study of water transport on a generic mirror, International Conference on Multiphase Flow,ICMF, Tampa, FL, US, 2010.

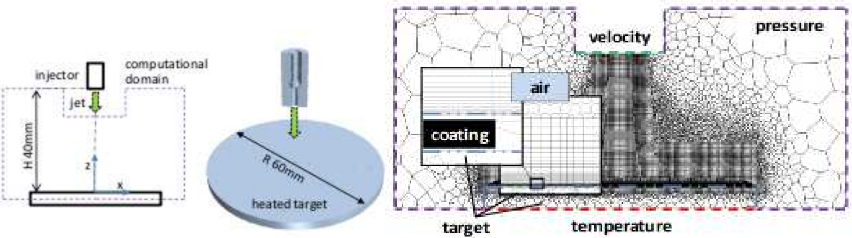




- Real engine

- Simplified case
- Piston top simplified as a series of horizontal and inclined plans
- Impinging jet flow and heat transfer

ENGINES: EXP & SIMULATIONS



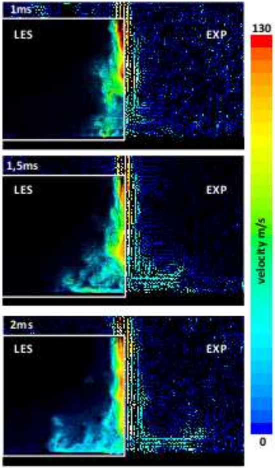
(A) Setup (B) Computational domain

FIGURE: Simplified setup

M. Bovo and L. Davidson "Direct comparison of LES and experiment of a single-pulse impinging jet", International Journal of Heat and Mass Transfer, Vol. 88, pp. 102-110, 2015.

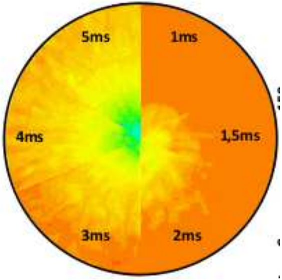
ENGINES: RESULTS

Velocities at three instants

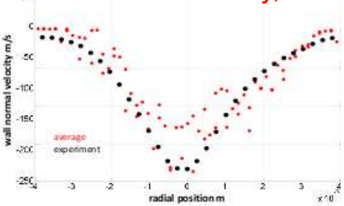


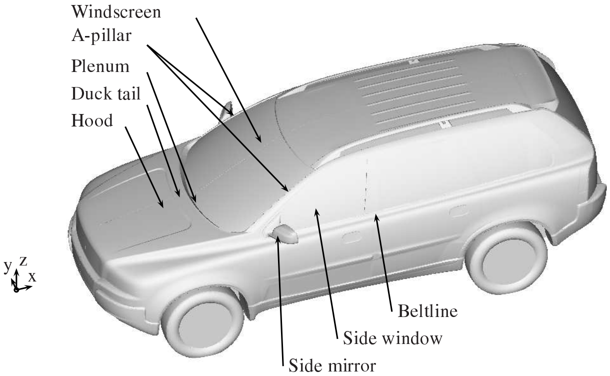
(A) Velocities at three instants.

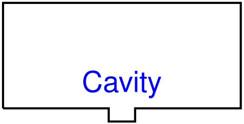
Surface temperature



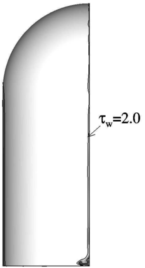
wall normal velocity, 0.6*ms*



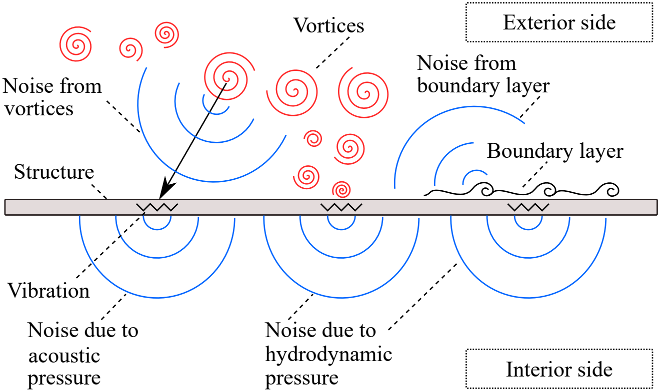

Windscreen
A-pillar
Plenum
Duck tail
Hood
y
z
x
Beltline
Side window
Side mirror

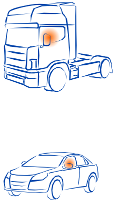

Cavity

side mirror

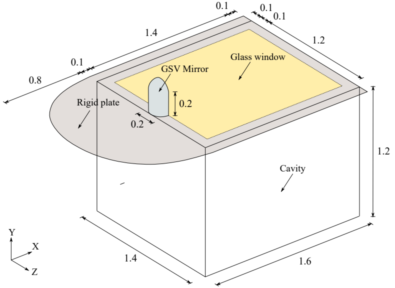

τ_w=2.0

- An important source of the interior noise in vehicles is the window vibration that is excited by
  - the exterior flow (indirect noise generation).
  - the exterior flow-induced noise (direct noise transfer).

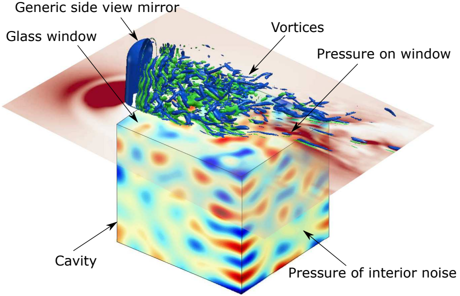




- The exterior turbulence creates interior noise by making the window glass vibrate



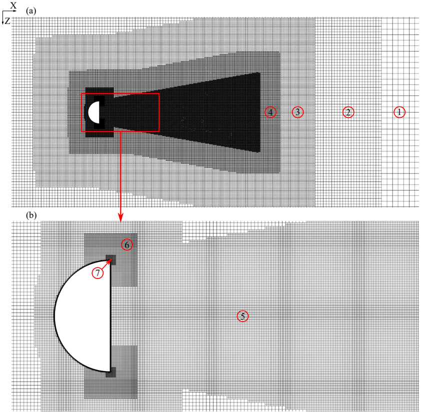
(A) Domain with mirror, glass window and cavity.



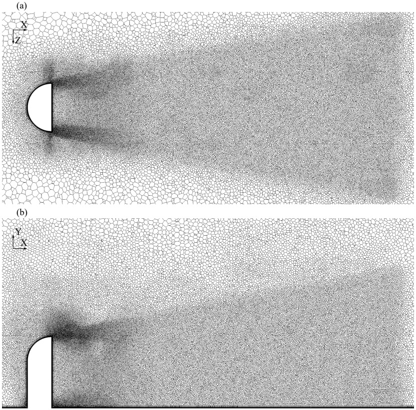
(B) CFD, vibrating window, noise propagation in cavity.

H.-D. Yao & L. Davidson, "Generation of interior cavity noise due to window vibration excited by turbulent flows past a generic side-view mirror", Phys. Fluids, Vol. 30, 036104, 2018

- Compressibility: compressible vs. incompressible.
- Turbulence modeling: detached eddy simulation vs. large eddy simulation.
- Acoustics: direct vs. indirect simulation using acoustic perturbation equations.
- Grid topologies: trimmed vs. polyhedral cells.

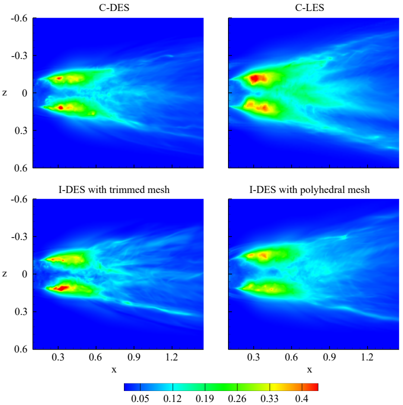


Trimmed mesh

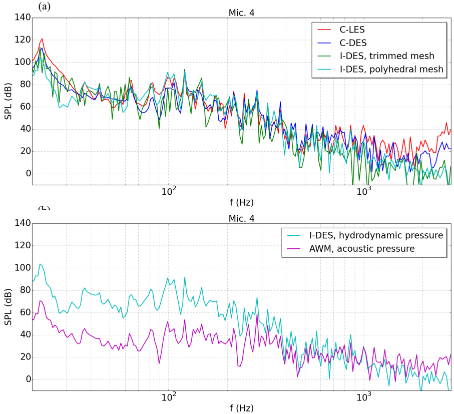


Polyhedral mesh

- The contributions of the exterior hydrodynamic and acoustic pressure fluctuations to the interior noise generation are addressed.



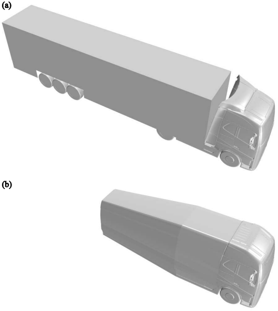
(A) RMS values of surface pressure fluctuations



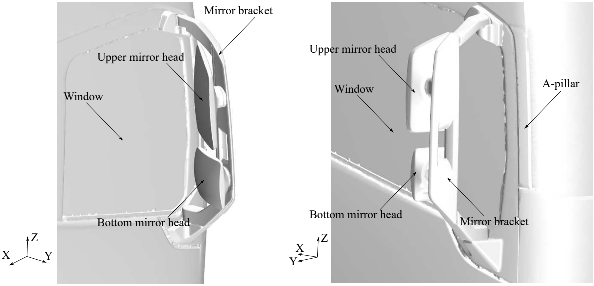
(B) SPLs of interior noise at Mic. 4 (bottom corner)

APPLICATION 2 – FULL-SCALE TRUCK (1)

- The installation effect of a side-view mirror is studied.
- The simplification strategy for a full-scale production truck is validated.



Original and simplified trucks

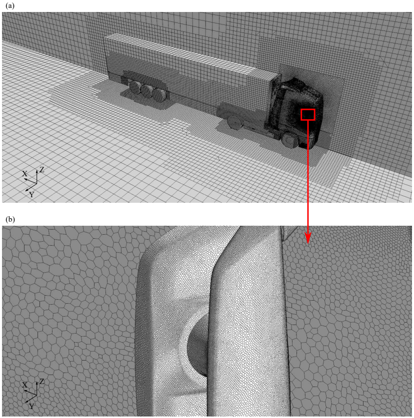


Side-view mirror components, the A-pillar and the window

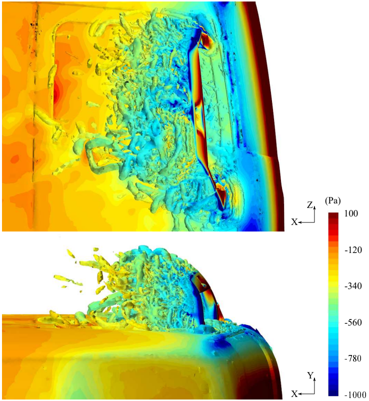
H.-D. Yao & L. Davidson, “Simplifications Applied for Simulation of Turbulence Induced by a Side View Mirror of a Full-Scale Truck Using DES”, SAE 2018-01-0708, 2018.
H.-D. Yao, L. Davidson, Z. Chroneer, “Investigation of interior noise from generic side-view mirror using incompressible and compressible solvers of DES and LES”, SAE 2018-01-0735, 2018.

Application 2 – Full-Scale Truck (2)

- A hybrid mesh of trimmed and polyhedral cells is employed.
- The mesh is sufficiently refined near the mirror and A-pillar to resolve turbulent flow structures.

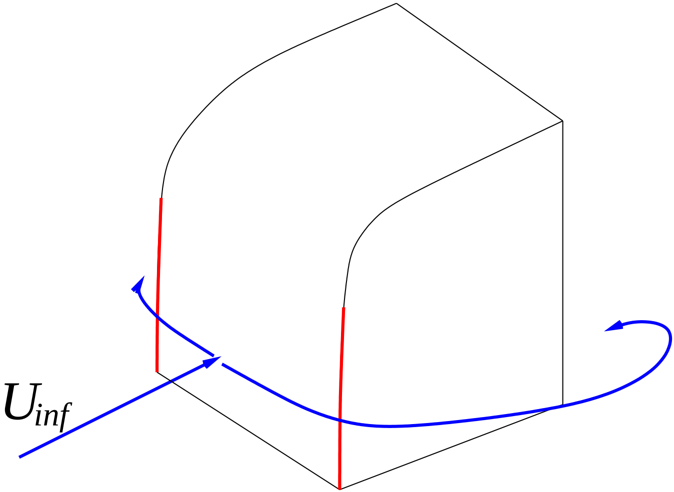


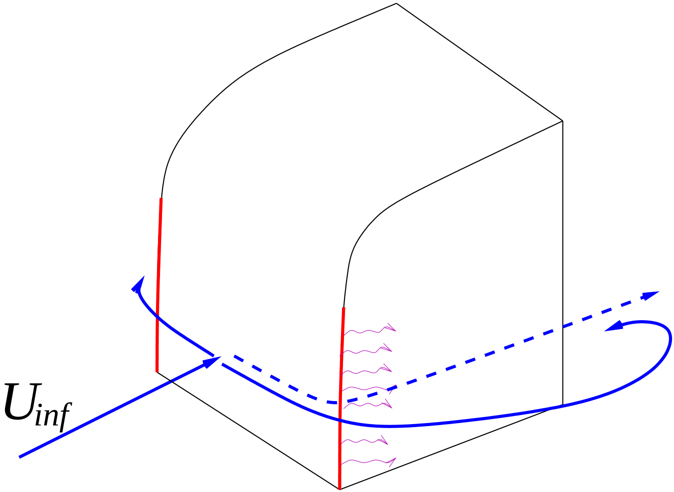
A hybrid mesh of trimmed & polyhedral cells

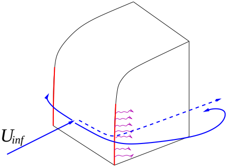


Snapshots of Q-criterion

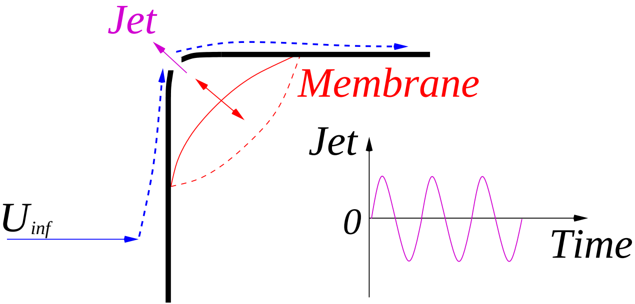
AERODYNAMICS: AB VOLVO, FFI PROJECT 2013-2018


U_{inf}

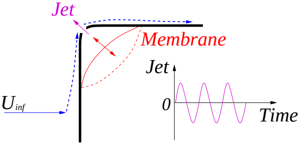

U_{inf}

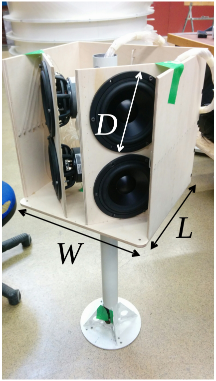


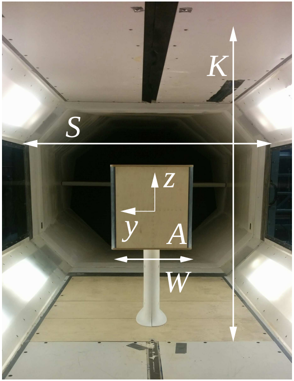
U_{inf}

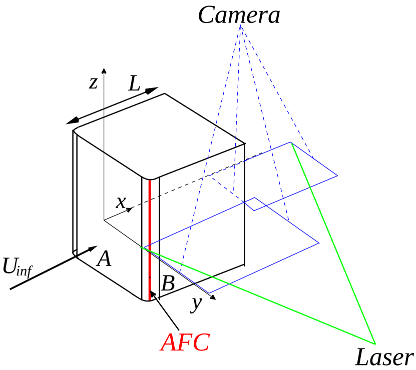


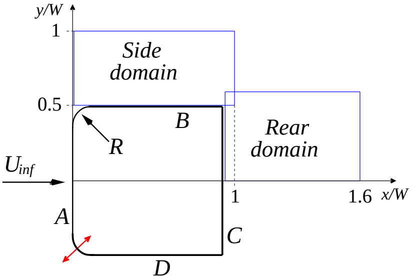
Jet
Membrane
Jet
0
Time
U_{inf}


Jet
Membrane
Jet
0
Time
U_{inf}


D
L
W


K
S
z
y
A
W

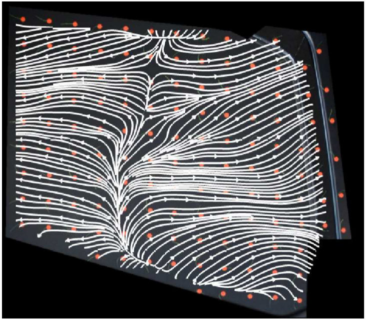

Camera
z
L
x
U_{inf}
A
B
y
AFC
Laser


y/W
1
Side
domain
0.5
B
R
Rear
domain
U_{inf}
1
1.6
x/W
A
C
D

G. Minelli, E. Adi Hartono, V. Chernoray, L. Hjelm and S. Krajnovic “Aerodynamic flow control for a generic truck cabin using synthetic jets”, Journal of Wind Engineering and Industrial Aerodynamics, Vol. 168, pp. 81-90, 2017.

AFC OFF

AFC ON



G. Minelli, S. Krajnovic, B. Basara and B. Noack, “Numerical Investigation of Active Flow Control Around a Generic Truck A-Pillar”, Flow, Turbulence and Combustion, Vol. 97, pp. 1-20, 2016.

FIGURE: Internal engine combustion of mixture of air and direct injected diesel.

IMPINGING JET

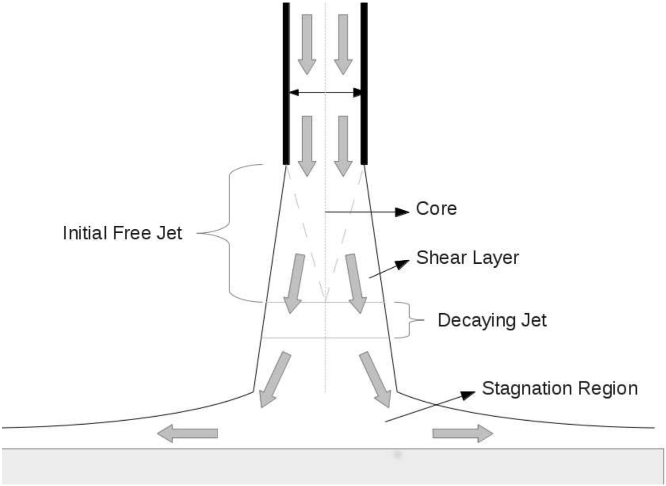
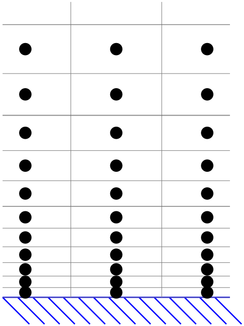
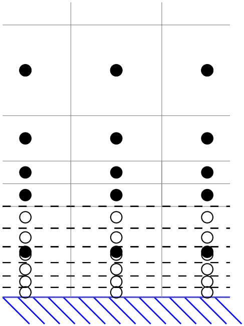


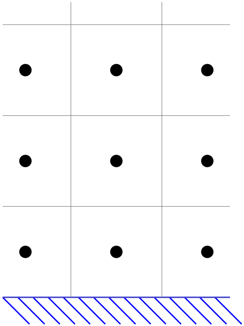
FIGURE: Turbulent axisymmetric impinging jet.



Mesh for low-Reynolds-number, LRN, modeling



Mesh for Numeric Wall Function, NWF



Mesh for high-Reynolds-number, HRN, modeling

WALL FRICTION

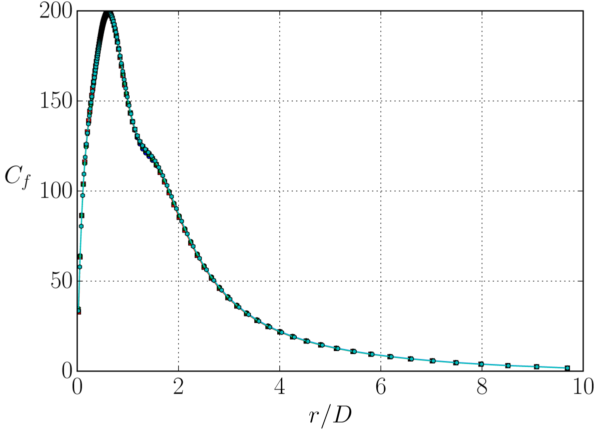
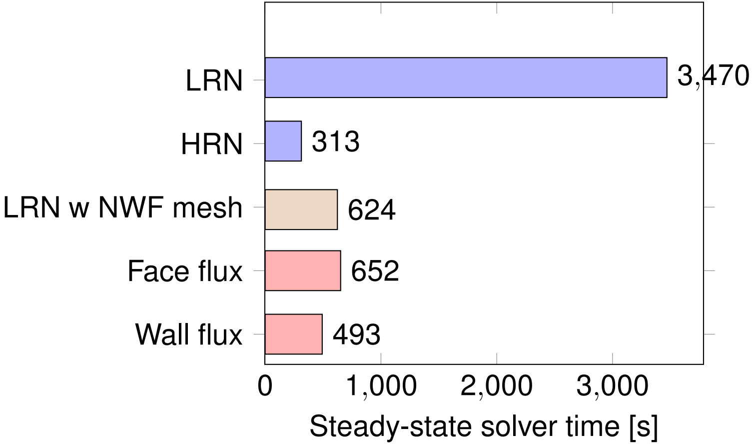


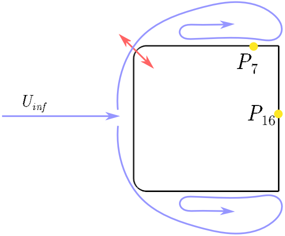
FIGURE: Impinging jet at $Re_D = 220000$, comparing; ▬ : default LRN, ▬ : LRN with NWF mesh, ▬ face flux, ▬ : wall flux.

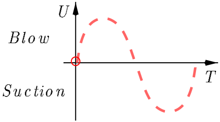


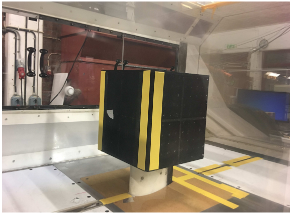
J.-A. Bäckar, L. Davidson, “Evaluation of numerical wall functions on the axisymmetric impinging jet using OpenFOAM”, *International Journal of Heat and Fluid Flow*, Volume 67, pp. 27-42, Part A, 2017.

AFC AND MACHINE LEARNING

- Project leaders: S. Krajnović and V. Chernoray







- Left: A sketch of the flow separation
- Right: The model placed in the wind tunnel
- Object: teach the controller to miminize drag by finding optimal A_1, A_2, f_1, f_2 in $S = A_1 \sin(2\pi f_1 t) + A_2 \sin(2\pi f_2 t)$
- Learning procedure is based on a genetic algorithm (GA) optimization script

Applied and Fundamental Research: How to

- There is a danger that very applied FFI projects get higher priority than fundamental research

APPLIED AND FUNDAMENTAL RESEARCH: HOW TO

- There is a danger that very applied FFI projects get higher priority than fundamental research
- How to combine applied & fundamental research?

Applied and Fundamental Research: How to

- There is a danger that very applied FFI projects get higher priority than fundamental research
- How to combine applied & fundamental research?
  - Choose the right partner (persons) in industry

Applied and Fundamental Research: How to

- There is a danger that very applied FFI projects get higher priority than fundamental research
- How to combine applied & fundamental research?
  - Choose the right partner (persons) in industry
  - In a project: do both fundamental research (first) and then apply it (maybe by your industrial partner)

Applied AND Fundamental Research: How to

- There is a danger that very applied FFI projects get higher priority than fundamental research
- How to combine applied & fundamental research?
  - Choose the right partner (persons) in industry
  - In a project: do both fundamental research (first) and then apply it (maybe by your industrial partner)
  - Go out and visit the industry; make presentations.