IMPERIAL

Linear instabilities with the Incompressible solver

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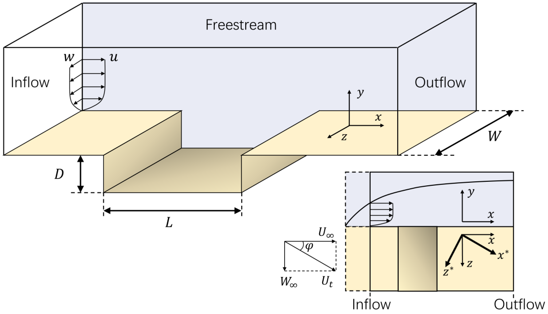
Domain

Data

- $\mathsf{L}/\mathsf{D} = 4$
- $\mathsf{W}/\mathsf{D} = 2$
- $\varphi_{\mathsf{sweep}} = 30°$
- Reynolds studied (based on the depth of the gap): $\mathsf{Re}_{\mathsf{D}} = 1500, 7500$

Mesh (quasi-3D simulations)

- Element-based mesh in the plane $\mathsf{x} - \mathsf{y}$.
- Fourier expansion in z direction.
- 5th-order polynomial expansion for the velocity field and 4th-order for the pressure, in the hp/Spectral formulation.

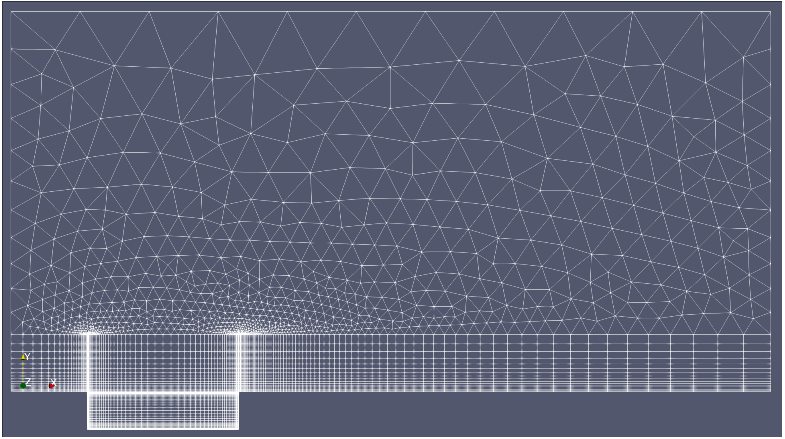


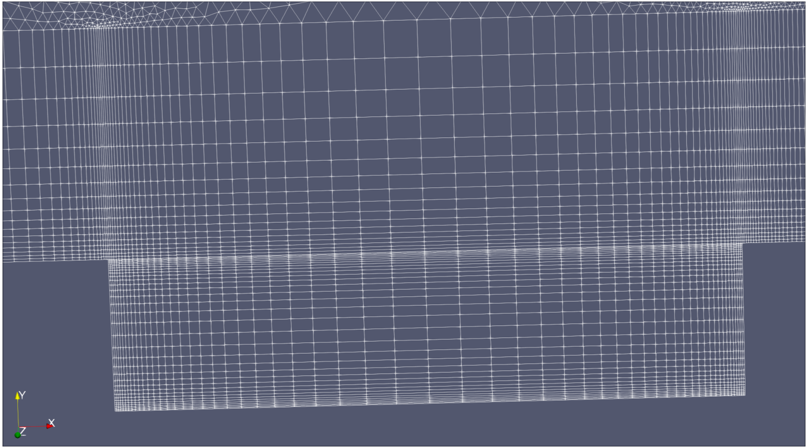
From Ganlin's thesis

Domain

Boundary conditions

- Inlet & outlet flows.
- Free stream at the top and no-slip at the bottom.
- Periodic in z direction.




Y
X
Z

Baseflow

- Quasi-3D simulations with 16 Fourier modes in the z direction at $\mathrm{Re_D} = 1500$ lead to a 2D stable baseflow (see pictures below).
- Quasi-3D simulations with only the constant mode in the z direction at $\mathrm{Re_D} = 7500$ lead to an unstable baseflow, which after using a feedback control in order to stabilize the problem, we get a baseflow similar to one the below.

u component

v component

w component

Preliminary LSA results ($\mathrm{Re_D} = 7500$)

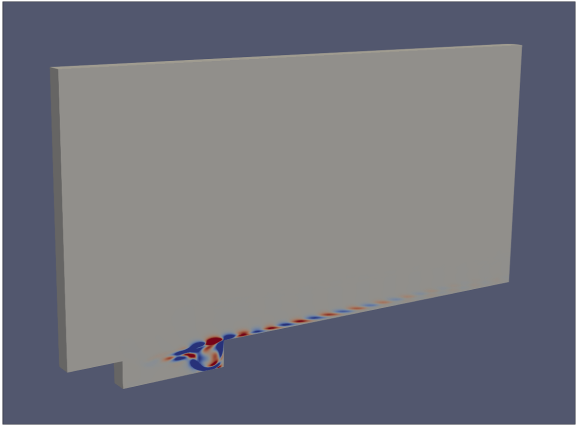
Single mode simulations by modifying the length of the domain in the z direction. In each case we assume that the perturbation is of the form:

$$\tilde{u}(x, y, z, t) = q(x, y) \exp(i\beta_n z) \exp(\lambda t) + c.c.$$

where $\beta_n = 2\pi n / L_z$ is the mode. We ran the linear Navier-Stokes for $n = 1, \ldots, 8$ in order to see which eigenpairs (λ, q) are unstable.

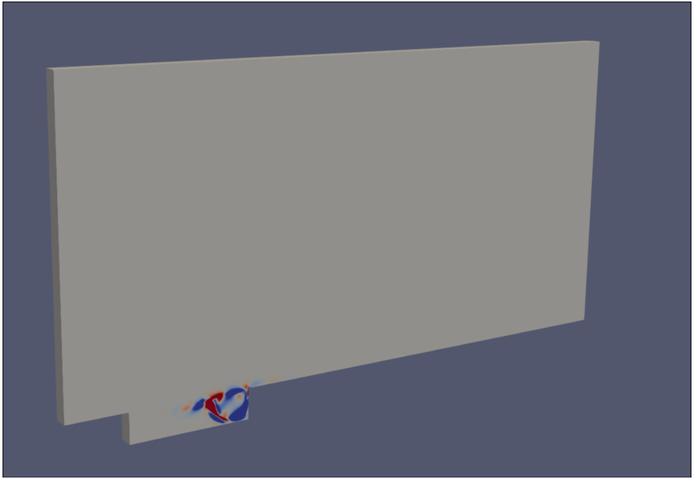
Modes 1, 2, 5, 6, 7 and 8 are stable.

The leading eigenvalues of modes 3 and 4 have positive real part leading also to an instability.

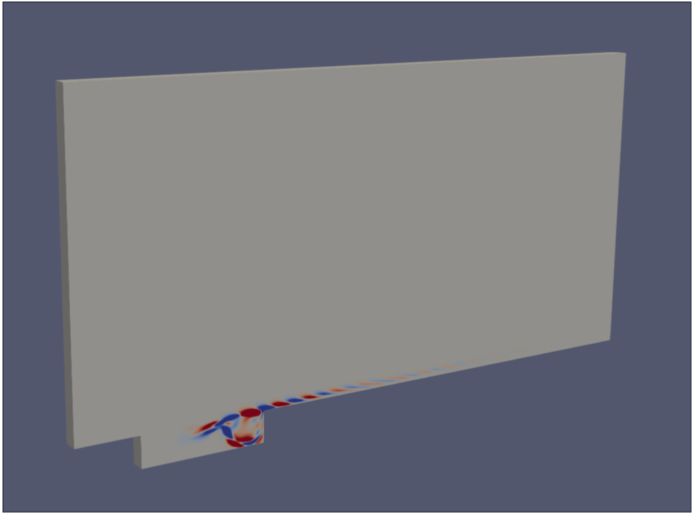


u component of the velocity of an unstable mode with β_3

All the unstable modes that we plot so far look similar. Also w component is similar to u component.



v component of the velocity of the same unstable mode of above, with β_3



u component of the velocity of an unstable mode with β_4

Next steps, questions

- How can we distinguish between convective instabilities within the gap and absolute instabilities? Because the domain is periodic in the z direction, so a priori the latter ones may camouflage the former ones.
- Is the domain appropriate for Boeing's problem? Specific data is needed. Should we change the length ratios (1st slide)? In particular, the sweep angle may influence the appearance of certain unstable modes or not.
- Are we interested in the onset of the instabilities as a function of the Reynolds number?
- Should we start doing DNS simulations with the compressible solver?