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ENCAPSULATED FORMULATION OF THE SELECTIVE FREQUENCY DAMPING METHOD

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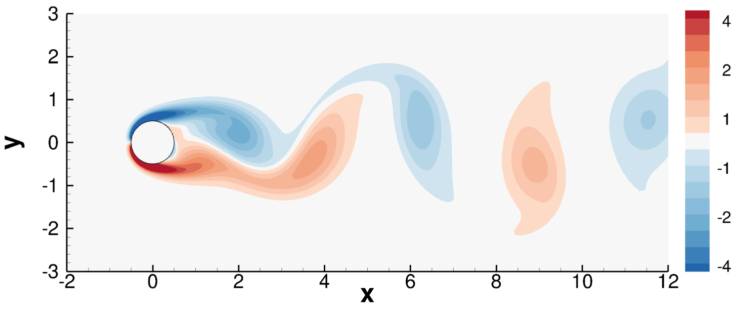
When analysing the stability of fluid flows, knowing unstable equilibria of the Navier-Stokes equations is crucial. This steady-state solution can then be used to computed stability analysis.

In [1], Akervik *et al.* presented a method, called Selective Frequency Damping (SFD), to reach the steady-state of a system by damping the unstable temporal frequencies. As it can be implemented by adding a linear forcing term into an existing code and does not need an initial guess of the solution, this method appeared to be an efficient alternative to classical Newton's methods.

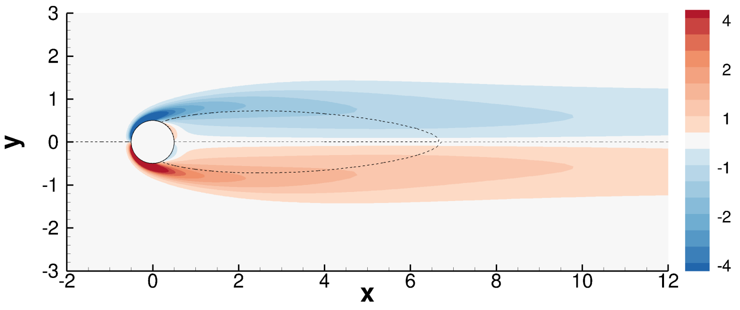
We present an alternative "encapsulated" formulation of the SFD method. This (time-discrete) formulation makes use of splitting methods [2], which means that it can be wrapped around an existing time-stepping code as a "black box". Hence the implementation of a steady-state solver is very easy because the existing unsteady solver does not need to be modified. It is simply called each time-step and a linear operator (modelling a feedback control and a low-pass time filter) is applied to its outcome.

The method is first applied to a scalar problem in order to analyse its stability and highlight the roles of the control coefficient and the filter width in the convergence (or not) towards the steady-state. We will see that the the method relies on the oscillatory growth of the system studied. Hence the method is not able to stabilize problems with a pure exponential growth of the unstable eigenmodes (*e. g.* wall confined jets [4]).

Then the steady-state solution of the incompressible flow past a two-dimensional cylinder at $Re = 100$ is presented. This result has been obtained with a code which implements the spectral/hp element method and is identical to the one presented by Barkley [3].



(a) Snapshot of the uncontrolled flow.



(b) Unstable steady-state obtained by SFD.

Figure 1: Vorticity of the incompressible flow past a two-dimensional cylinder at $Re = 100$.

Finally we discuss the possibility of coupling the SFD method with an Arnoldi method. The goal is to approximate the eigenmodes of an unstable flow and then to adjust the parameters of the SFD method to ensure convergence towards the steady-state. This coupling appeared to be valuable when flows of interest for the automotive and aeronautics industries are studied (*e. g.* co-rotating vortices).

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