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MODAL RESPONSE OF INCOMPRESSIBLE FLOW TO EXTERNAL ACTUATION

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In the present paper we present a method to query the flow for physical modes answer to a given form of actuation. Stability properties of the fluid flow are of particular interest in many areas of fluid mechanics [1, 2]. With the knowledge of linear stability we gain information about flow development and transition. In practical applications even more interesting is flow response to forcing and actuation [3].

In particular, actuation for flow control uses often a periodic signal with the parameters related to structures emerging in the fluid due to the actuation. The stability properties of the flow and the modal analysis of the flow field presented here can serve as the first approximation for the actuation system development limiting the myriads of possible configurations to few used in further tests.

For development of the method presented here we applied linearized Navier-Stokes equations and CFD tools. In presented here examples we used incompressible flow model and FEM solver for 2D and 3D. We introduce the actuation within the computational domain or on boundaries of the flow obtaining the clear response of the flow in the whole domain. In this way we are able to query different regions for modal response to the actuation. For example, in bluff-body wake flow one can distinguish different flow regions characterized by different instabilities. Global instability of the wake, instability of shear layers bounding the wake, instabilities of boundary layer on the bluff body surface are important in transition from laminar steady state to turbulent, unsteady one. These modes can be clearly extracted with the present method from the analyzed model even if having negative growth rate. For control and instability even damped modes are of interest because due to non-normality even damped modes can result in transient growth. As Reynolds

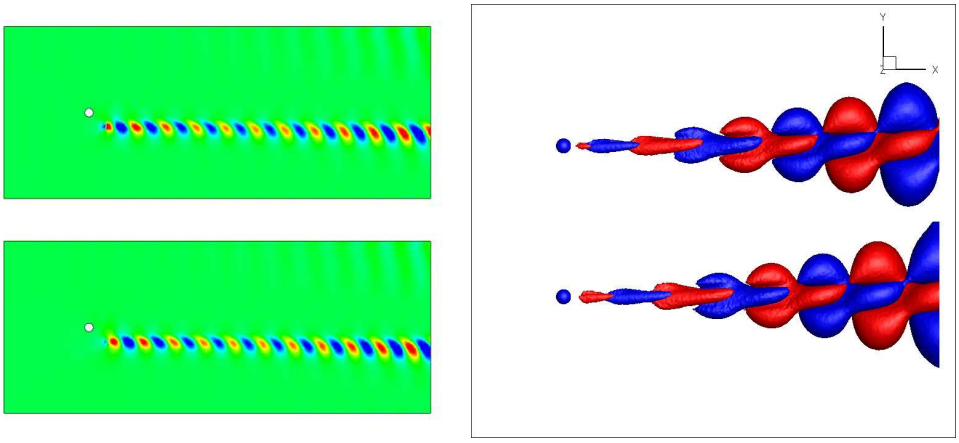

Figure 1: Real and imaginary part of the modal response to a point actuation (left, circular cylinder flow at $Re = 100$) and sphere motion (right, $Re = 300$). On the left figure vorticity field is depicted. Right figure shows transversal iso-velocity surfaces.

number increases or external actuation is being supplied damped modes are becoming amplified. With presented method we can investigate the wide spectrum of modes. This differs the presented method from receptivity studies with the use of Navier-Stokes equations solvers or postprocessing and modal analysis of regular CFD simulations with DMD [4] or POD [5].

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