Investigation of a Steady-State Laminar Separation Bubble and its Global Instability

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A *laminar separation bubble* (LSB) can originate if an initially laminar boundary layer is subject to a sufficiently strong adverse pressure gradient, and transition occurs due to an instability in the flow. Usually, the turbulent, highly unsteady flow reattaches in the mean further downstream, forming a closed bubble. LSBs can occur on slender bodys and may adversely affect their performance in terms of lift, drag, and noise production.

The method of selective frequency damping[1] allows to compute steady-state separation bubbles by suppressing instability mechanisms by means of a forcing term added to the right-hand side of the Navier-Stokes equation. A separation bubble obtained with this method is laminar both at separation and at reattachment. In such a case, the bubble is closed, i.e. the flow is reattached, not as a result of laminar-turbulent transition, but due to a favorable pressure gradient.

The resulting steady-state LSB (Fig. 1, left) is highly unstable. If the LSB is subject to a small perturbation, this perturbation will initally grow due to a linear mechanism. Two types of linear instabilities can be distinguished: *local* and *global instability*. A local linear instability is typically investigated based on the Orr-Sommerfeld equation, assuming locally parallel flow, and has been the subject of numerous studies. In contrast, global instability is by far less investigated and shall be studied by means of the linearized Navier-Stokes equations here. A global disturbance function is visualized in Fig. 1, right.

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[1]E. Åkervik, L. Brandt, D. S. Henningson, J. Hoepffner, O. Marxen, and P. Schlatter. Steady solutions of the Navier-Stokes equations by selective frequency damping. Phys. Fluids, 2006. Accepted.

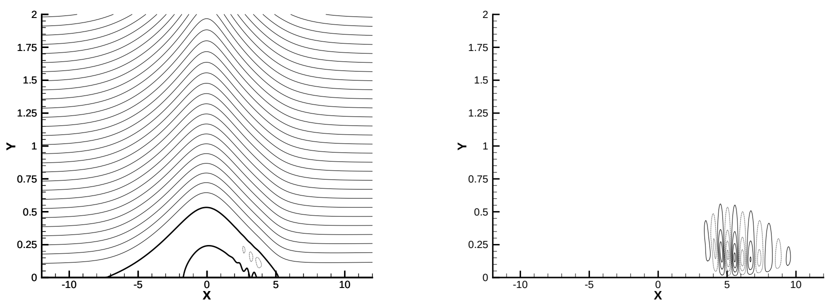

Figure 1: Left: Streamlines of the steady-state LSB. Right: Contours of the instantaneous wall-normal disturbance velocity.