Numerical Aspects of the Implementation of Artificial Boundary Conditions for Laminar Fluid-Structure Interactions

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Introduction: When truncating an unbounded domain to a finite one for CFD, artificial boundaries (a.b.) appear. What are the proper boundary conditions?

Computational Methods: We consider the case of small body moving at constant velocity parallel to a wall. In an appropriate frame, the velocity field $\boldsymbol{u}$ as seen from the body is described by

$$\boldsymbol{u} \cdot \nabla \boldsymbol{u} + \nabla p - \nu \Delta \mathbf{u} = 0$$
$$\nabla \cdot \boldsymbol{u} = 0$$

where p is the pressure and ν the dynamic viscosity of the fluid.

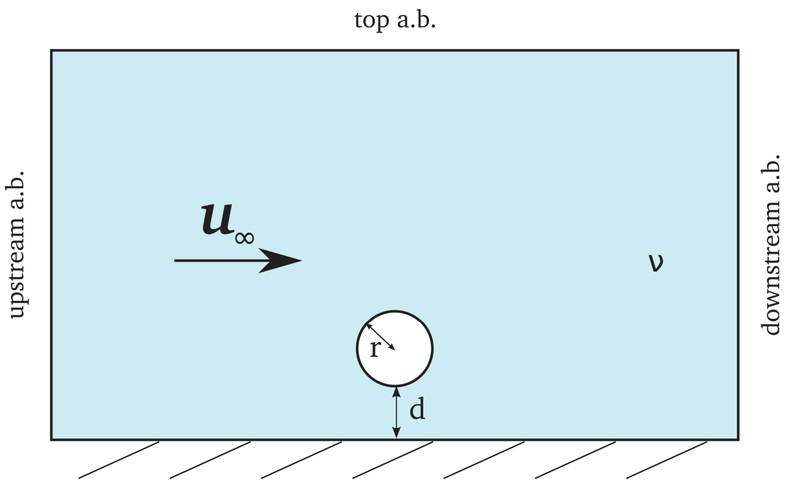

Figure 1. Sketch of the domain and body.

The boundary conditions on the wall are given by

$$\boldsymbol{u}\Big|_{y=0} = \boldsymbol{u}_\infty$$

The conditions at the body may be Slip or No-slip, the condition at the artificial boundaries are:

- Velocity-at-infinity (s.b.c.): $\boldsymbol{u}_\infty$ on all a.b., see *e.g.* [1].
- Open-boundaries (c.b.c.): $\boldsymbol{u}_\infty$ on inlet, Normal stress with $f_0 = 0$ on other a.b., see *e.g.* [2].
- Adaptive (a.b.c.): asymptotic expansion of the mathematical solution given in [3] at all a.b.

Results: We present the impact of the choice of boundary conditions in **Fig. 2.**

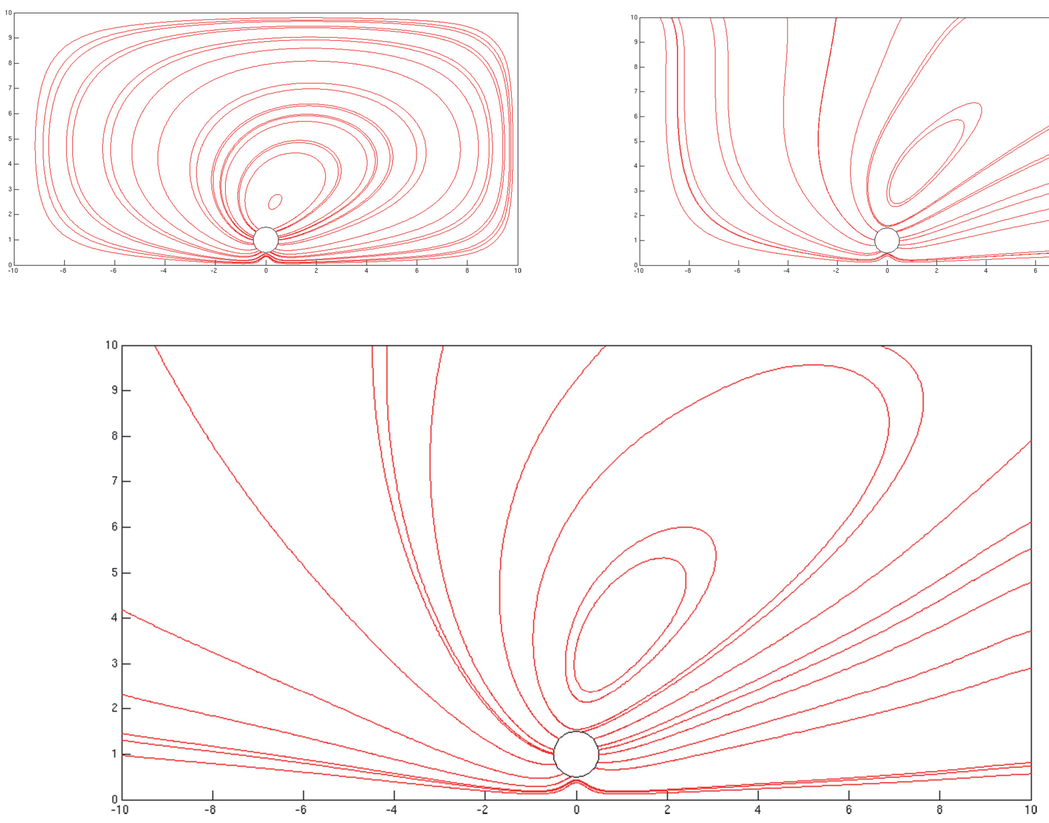

Figure 2. Streamlines of $\boldsymbol{u} - \boldsymbol{u}_\infty$, with s.b.c., c.b.c., and a.b.c (bottom).

Moreover, the accuracy on lift and drag is improved, see **Fig. 3.**

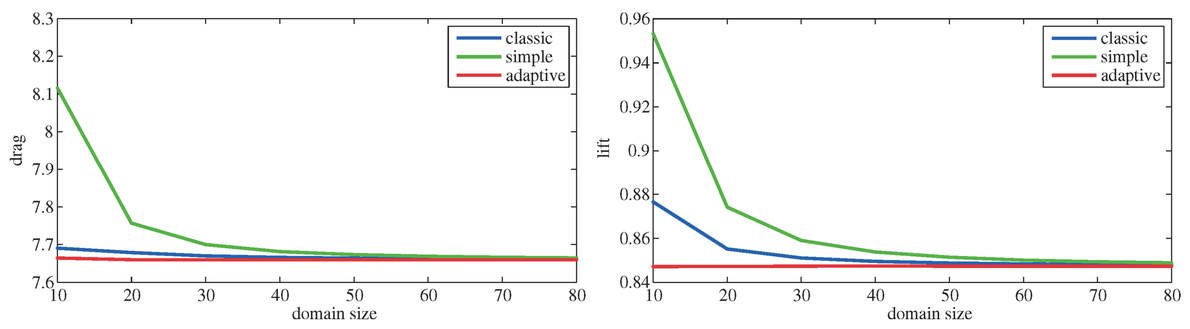

Figure 4. Drag and lift as a function of domain size.

Conclusions: The a.b.c. improve the qualitative behavior of the flow and the accuracy of lift and drag, especially in small domains (efficient memory use).

References:
1. L. Zeng, S. Balachandar and P. Fischer, *JFM*, **536**, 1-25 (2005)
2. B. Chen, T. Kawamura and Y. Kodama, *Proc. 17th CFD Symp.*, Tokyo, No. E8-3 (2003)
3. C. Boeckle and P. Wittwer, *arXiv.org*, 1208.3648 [sub. *Comp. & Fl.*]