Coherent Vortex Simulation (CVS) of an impulsively started cylinder at Re=3000 using an adaptive wavelet method with penalisation

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Recently, we proposed a new turbulence model, called Coherent Vortex Simulation (CVS) [2, 3], for computing fully developed turbulent flows. This new approach for CFD is based on the observation that turbulent flows contain both an organized part (the coherent vortices) and a random part (the incoherent background flow). The CVS method is based on the computation of the coherent part of the vorticity in an adaptive wavelet basis, while the influence of the incoherent background flow is statistically modelled. To be able to compute flows near walls or past obstacles we coupled the adaptive wavelet method [6, 4] with the penalisation method [1], for more details we refer to [7]. Therewith solid walls or obstacles are modelled as a porous medium with porosity η tending to zero. Assuming incompressibility of the flow we use the vorticity-velocity formulation, and obtain

$$\partial_t \omega + \vec{V} \cdot \nabla\omega - \nu \nabla^2 \omega + \nabla \times (\frac{1}{\eta} \chi (\vec{V} - \vec{V}_0)) = 0 \quad (1)$$

where ω is the vorticity, $\vec{V}$ the velocity, $\vec{V}_0$ the velocity of the obstacle and ν the kinematic viscosity. The complex geometry is simply described by the mask function $\chi(\vec{x})$ set to 1 inside the solid regions and to 0 elsewhere.

Here we present an application of a flow past an impulsively started cylinder at $Re = 3000$ proposed in [5]. The numerical difficulty comes from the fact that due to the impulsive start a thin boundary layer develops and that the drag coefficient exhibits a $t^{-1/2}$ singularity. In Fig.1 we show the vorticity field for two time instants together with the corresponding locally refined grid depicted in Fig.2. We observe that the grid automatically adapts to the obstacle and follows the flow evolution. A comparison of the time evolution of the drag coefficient for different methods shows the validity of the CVS wavelet method. Note that compared with a DNS only less than 8% of the total number of modes are used.

References

[1] Angot, P., Bruneau, C.H., Fabrie, P., *Numer. Math.***81**, (1999) 497–500.

[2] M. Farge, K. Schneider and N. Kevlahan. *Phys. Fluids*, **11**(8), 2187–2201, 1999.

[3] M. Farge and K. Schneider. Coherent Vortex Simulation (CVS), a semi–deterministic turbulence model using wavelets. *Flow, Turbulence and Combustion*, in press.

[4] J. Fröhlich and K. Schneider. *J. Comput. Phys.* **130**, 174–190, 1997.

[5] P. Koumoutsakos and A. Leonard. *J. Fluid Mech.*, **296**, 1–38, 1995.

[6] K. Schneider and M. Farge. *C. R. Acad. Sci. Paris Série II*, **328**, 263–269, 2000.

[7] K. Schneider. An adaptive wavelet method for 2D turbulence in complex geometries. Preprint. CMI Université de Provence, Marseille 2001.

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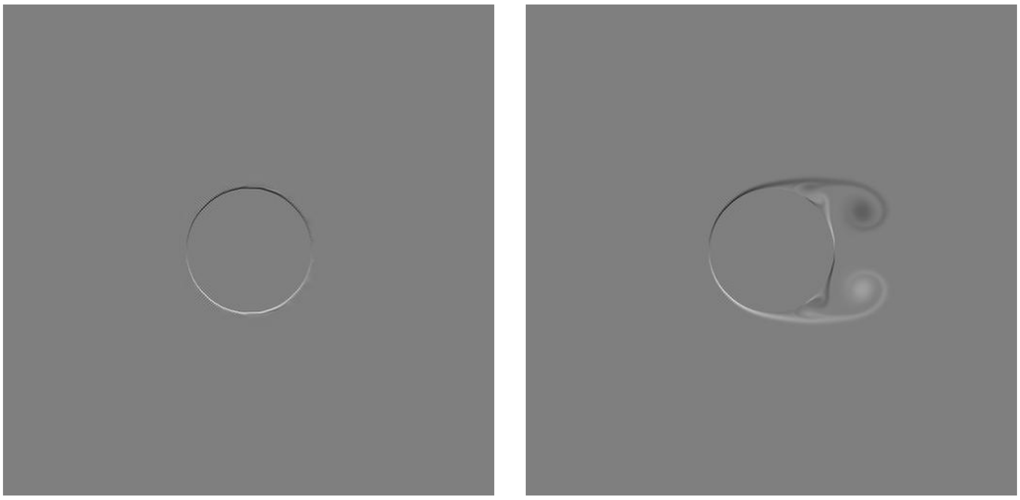

Figure 1: CVS of an impulsively started cylinder at $Re = 3000$. Vorticity at $t = 0.1, 4$.

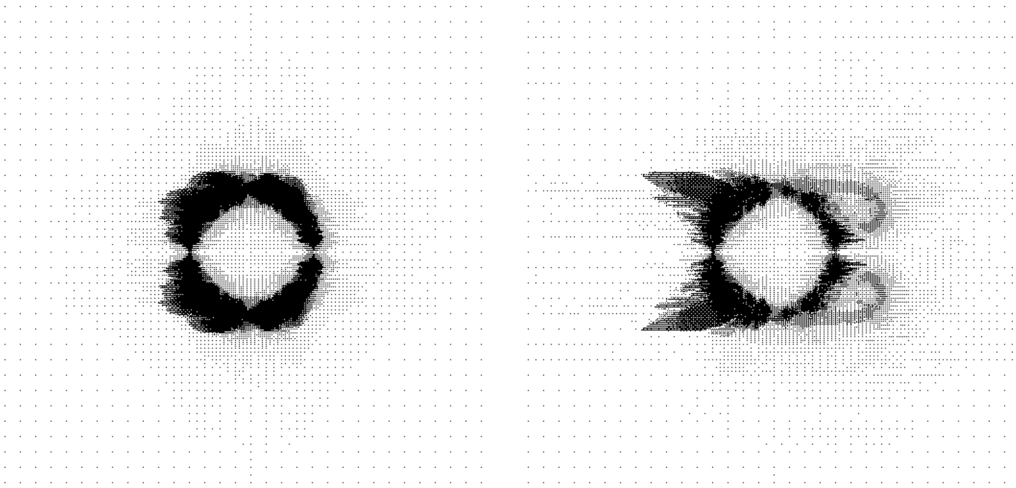

Figure 2: Corresponding grid in physical space. Note that at $t = 0.1$ only 18607 and at $t = 4$ only 20267 out of $512^2 = 262144$ wavelet modes are used.

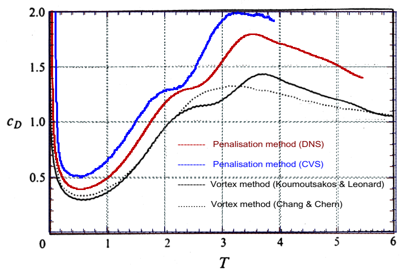

Figure 3: Comparison of the time evolution of the drag coefficient between CVS, DNS and vortex methods [5].