Dynamics of flows with helical symmetry

Ivan Delbende[*†], **Maurice Rossi**[*‡], **Benjamin Piton**[*†]

[*]Université Pierre et Marie Curie-Paris 6 (UPMC), France

[†]Laboratoire d'Informatique pour la Mécanique et les Sciences de l'Ingénieur (LIMSI-CNRS)
BP 133
91403 Orsay Cedex, France
e-mail: *Ivan.Delbende@limsi.fr, Benjamin.Piton@limsi.fr* – web page: *http://www.limsi.fr/*

[‡]Institut Jean Le Rond d'Alembert (IJLRA-UPMC)
4 place Jussieu
case 162
75232 Paris Cedex 05, France
e-mail: *Maurice.Rossi@upmc.fr* – web page: *http://www.dalembert.upmc.fr/*

ABSTRACT

Vortices shed in the wake of rotating devices such as propellers, wind turbines and helicopter rotors often display a helical symmetry, meaning that they are, at least locally, invariant through combined axial translation and rotation. In the literature, the analytical [1,2] and numerical [3] works describing stationary helical vortices are mostly restricted to inviscid flows and to solutions with vorticity tangent to the helical lines along which the flow is invariant.

We have developed an original DNS code aimed at simulating the viscous dynamics of helical vortex systems without the above restrictions. Enforcing helical symmetry allows one to reduce the three-dimensional equations to a modified two-dimensional unsteady problem. The code thus takes into account 3D vortex curvature and torsion effects through the helical symmetry, but the resolution is of a 2D type [4], allowing for larger numbers of grid points and Reynolds numbers.

In this framework, we study the long-time (or equivalently far-wake) dynamics of systems with 2 and 3 helical vortices. Depending on the helix pitch and vortex core radius, two different types of merging are identified and conditions leading to one type of merging to the other are investigated in terms of bifurcations.

Helically symmetric flows are also produced by natural instability of axisymmetric jets, wakes and trailing vortices. DNS of the nonlinear saturation of such instabilities are presented here in the case of the Batchelor vortex. We retrieve the different behaviours observed when the swirl parameter is varied [5], and we present new results concerning the saturation of viscous centered modes [6].

REFERENCES

[1] J. C. Hardin *The velocity field induced by a helical vortex filament*, Phys. Fluids **25(11)**, 1949–1952, 1982.

[2] P. A. Kuibin, V. L. Okulov *Self-induced motion and asymptotic expansion of the velocity field in the vicinity of a helical vortex filament.*, Phys. Fluids **10**, 607–614, 1998.

[3] D. Lucas, D. G. Dritschel *A family of helically symmetric vortex equilibria*, J. Fluid Mech. **634**, 245–268, 2009.

[4] O. Daube *Resolution of the 2D Navier–Stokes equations in velocity/vorticity form by means of an influence matrix technique*, J. Comp. Phys. **103**, 402–414, 1992.

[5] I. Delbende, M. Rossi *Nonlinear evolution of a swirling jet instability*, Phys. Fluids **17(4)**, 044103, 2005.

[6] S. Le Dizès, D. Fabre *Large-Reynolds-number asymptotic analysis of viscous centre modes in vortices*, J. Fluid Mech. **585**, 153–180, 2007.