Numerical Modelling of Transitional and Turbulent Rotating-Flows with Walls Based on Pseudo-Spectral Techniques

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Among the various numerical methods developed for the solution of multi-dimensional and time-dependent incompressible flow problems, spectral methods are characterized by an outstanding numerical accuracy (one of the main properties of the Fourier series is its fast rate of convergence, which is exponential for infinitely differentiable functions). This kind of method provides a high numerical efficiency for a number of generic configurations by employing solvers based on FFT and fast direct Helmholtz solvers within optimized pressure-correction schemes.

In such situation, accurate predictions of flows involving very fine structures become possible and then, allow well-controlled numerical experiments, a requisite for studying instabilities properties during transition to turbulence. Coupled with linear (and non-linear) stability analysis such approach is very useful to capture the instability modes, in particular when they are characterized by traveling waves, as it is the case in a convectively unstable flow for example (Serre et al. 2004).

The continuous improvement of performances in the computing sciences allows us today to carry out direct numerical simulations (or Large Eddy Simulation, see Séverac et al. 2005) of fluid dynamics problems at high Reynolds numbers, keeping high-accurate solutions.

In this work, spectral approximations are mainly devoted to the study of confined rotating flows for which the rotation induced the coexistence of adjacent and coupled flow regions that are radically different in terms of the flow properties and the thickness scales of the very thin shear layers separated by a large non-viscous geostrophic core. Investigations are relevant to the cooling of gas turbines and turbomachinery and typical configurations are cavities between rotating compressors or turbine discs, between counter-rotating discs, between coaxial cylinders (Taylor-Couette flow, see for example Czarny et al. 2004) and in a rotor-stator system with or without throughflow (see Serre et al. 2001; 2001a).

References

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