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Spatial simulation of a co-rotating vortex merging process in unstable conditions.

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ABSTRACT

The present numerical study is motivated by the challenge to simulate the three-dimensional spatial dynamics of a co-rotating vortex pair [1], through the development of an elliptic instability [2], using a high order solver of the compressible Navier-Stokes equations. The numerical problem is the choice of boundary conditions: for the inflow and outflow conditions as well as for the lateral boundary conditions to represent a fluid at rest. Indeed, for these boundary conditions the problem comes from the no-zero circulation of the vortex system considered. The classic boundary conditions of Poinsot and Lele [3] based on the characteristics wave approach have been modified to be more adapted to the physics considered here. This new boundary condition is based on the assumption of an irrotational flow close to the borders (in order to determine the magnitude of the waves), as the vorticity field is concentrated on the computational domain center where the vortex system is initialy placed. To validate and evaluate the ability of this boundary condition to represent real conditions and their effects on the vortex dynamics, two- and three-dimensional temporal simulations were performed of a two co-rotating vortices dynamics. Then, two spatial simulations of the vortex breakdown phenomenon have allowed validating the numerical tools by comparison to the results of Ruith *et al.* [4]. The merging process of equal co-rotating vortices through the development of elliptic instability with axial velocity were simulated by $3D$ spatial simulations (Fig. [1]). Three vortex flow configurations were considered with different vortex systems and velocity peaks ratio (azimuthal and axial velocities).
The numerical development allowed to perform spatial simulations of vortex dynamics. Thus, the axial velocity effects are taken into account, which are neglected with the temporal approach. However, spatial simulations are limited by the computational resources (linked to the resolution and axial domain length to capture the merging process) and restricted to academic vortex flow configuration.

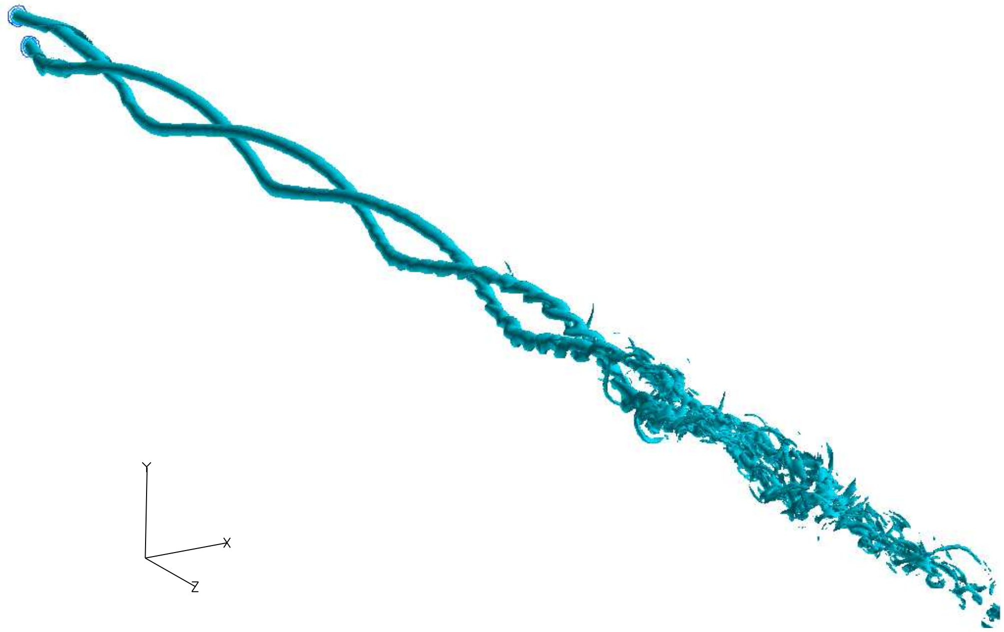

Figure 1: Spatial evolution of co-rotating vortices through the development of short wavelength instability illustrated by a selected isosurface of vorticity magnitude $|\omega| = 0.23|\omega_{max}|$.

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