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Abstracts

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3D numerical simulation of Batchelor vortices

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A new numerical technique to simulate three-dimensional (3D) incompressible flows based on the potential vector formulation is developed. The numerical technique combines finite differences on a non-uniform grid in the axial direction (n_z nodes), a Chebyshev spectral collocation technique in the radial direction (n_r nodes), and a Fourier spectral method in the azimuthal direction ($2n_\theta + 1$ modes). The technique is adapted to simulate 3D vortices, and we have tested it by solving the 3D rotating flow in a circular pipe, and comparing the resulting nonlinear travelling and stationary waves with previous stability[1] and numerical results.[2] Then, we used the numerical code to characterise the nonlinear stability properties of Batchelor's vortex. Several Reynolds number (Re), based on the maximum axial velocity and the radius of the core, and swirl paramenter (q), defined as the ratio between the maximum of the swirl and axial velocity, have been analysed in a domain which extend 200 core radius in the axial direction and 40 core radius in the radial one. The results found are in good agreement with previous ones from linear stability analysis.[3] As an example, figure 1 shows the axysimmetric streamlines ($n_\theta = 0$) for $Re = 200$ and $q = 0.3$. This axisymmetric solution is used as the base flow to simulate the 3D flow ($n_\theta \neq 0$). The perturbation of the velocity is shown in figure 2 ($n_\theta = 5$). The contour lines show a travelling wave from which we characterise the nonlinear instabilities properties of the base flow.

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[1]del Pino et al. *Fluid Dyn. Res.* **32**, 261–281 (2003)
[2]Barnes and Kerswell, *J. Fluid Mech.* **417**, 103–126 (2000)
[3]Mayer and Powell *J. Fluid Mech.* **245**, 91–114 (1992)

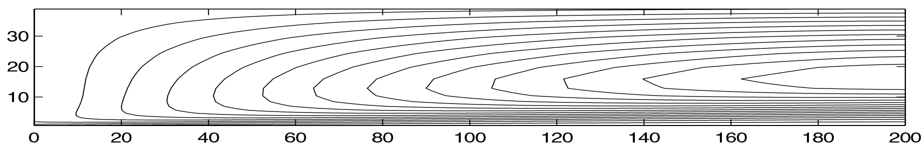

Figure 1: Contours of the stream-function for $Re = 200$ and $q = 0.3$ ($n_r = 30$, $n_z = 600$, $n_\theta = 0$)

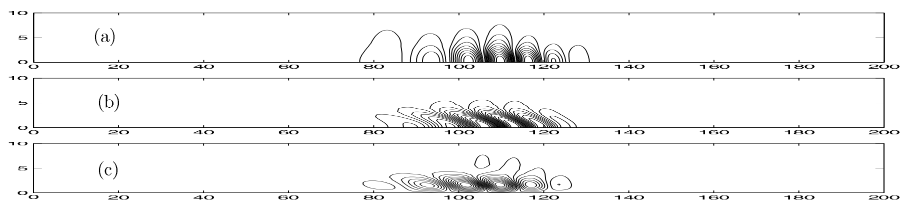

Figure 2: Perturbation of the velocity vector for $Re = 200$ and $q = 0.3$ ($n_r = 30$, $n_z = 600$, $n_\theta = 5$): (a) radial, (b) azimuthal and (c) axial velocity components.