Effect of stretching on vortices with axial flow: a three-dimensional stability study.

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In turbulent flows, vorticity-filament structures have been individuated in real or numerical experiments. Their evolution clearly depends on the varying background stretching field generated by surrounding vortices. In this context, numerical studies have been performed where the stretching field acting on a straight vortex is non-uniform, time-periodic or generated by an array of vortex rings. New stretched vortex solutions possessing an axial velocity, have recently been found by Gibbon *et al.* [1]. These basic flows, which satisfy the Navier–Stokes equations, describe a vortex possessing both azimuthal and axial velocities and subjected to a time-dependent strain field oriented along with its axis. These vortex solutions are interesting for two mains reasons : both axial and azimuthal vorticity are present and vorticity field is no longer aligned with a principal direction of strain. The stability governing the three-dimensional perturbations of such an unsteady stretched vortex is here addressed. These linear equations can be reduced by successive changes of variables to equations which are almost identical to those of the unstretched vortex but with time-dependent parameters. It is known that an unstretched swirling jet such as the Batchelor vortex, is unstable for large Reynolds numbers and intermediate swirl numbers q quantifying the ratio of azimuthal to axial velocity. Swirling jet instability are mainly dominated by inviscid negative helical modes. In the remaining part of the discussion, it is theoretically demonstrated how the simultaneous action of this swirling jet instability and stretching may destabilize the vortex. The three-dimensional stability equations are also numerically solved for the particular case of a Batchelor vortex which is first compressed and then stretched. Using this simulation, the destabilizing effect is confirmed. It is argued that it provides a possible mechanism for the vortex bursts observed in turbulence experiments.

References

[1] Gibbon, J. D., Fokas, A. S. & Doering, C. R. (1999) Dynamically stretched vortices as solution of the 3D Navier–Stokes equations. *Physica D* **132**, 497–510.