Instability and transition of steady and pulsatile flow in a stenotic tube

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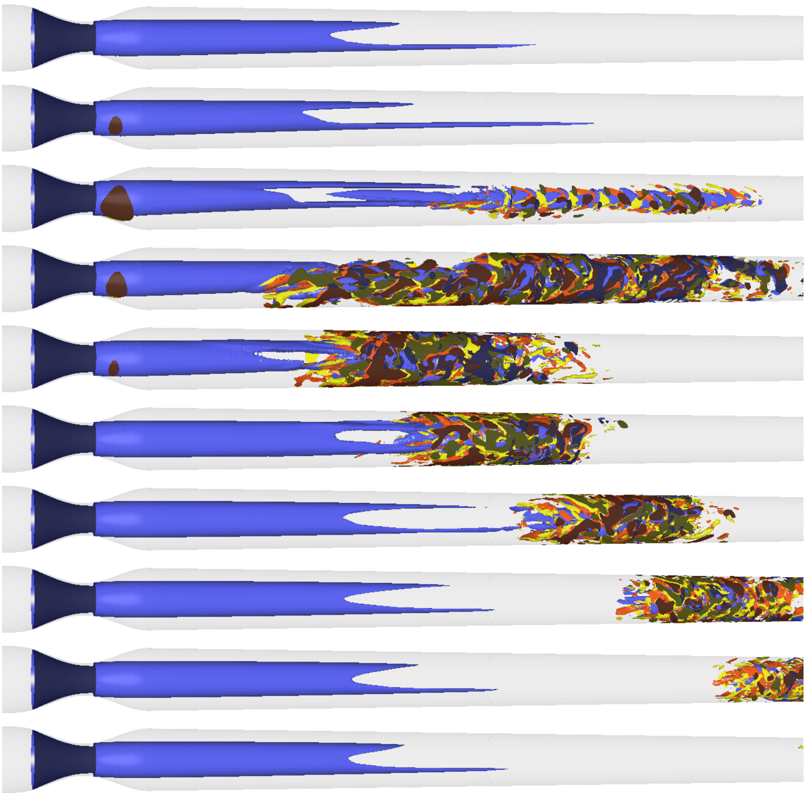
Steady inflow: jet flapping and turbulence

At low Reynolds numbers, a steady axisymmetric jet emanates from the separation line just downstream of the stenosis throat. In the geometry we have studied, a smooth 50% radial stenosis (contraction), the symmetric state has a linear instability at *Re*=722. The instability acts to deflect the jet from the centreline of the tube.

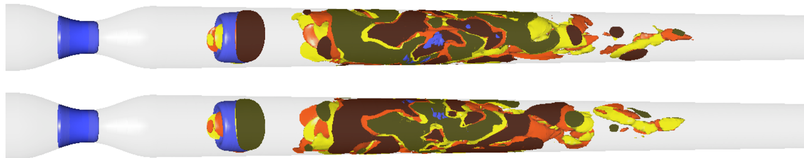
The sequence of images below, generated from DNS at *Re*=750, illustrates a long-timescale flapping of the jet which is quasi-repetitive. The blue isosurface is of the azimuthal vorticity component, and the red/yellow isosurfaces are of positive/negative axial vorticity component. After the jet achieves maximum deflection, there is a burst of turbulence that washes downstream as axisymmetry makes a partial recovery, allowing the cycle to start again.



Pulsatile inflow: alternate tilting of vortex rings

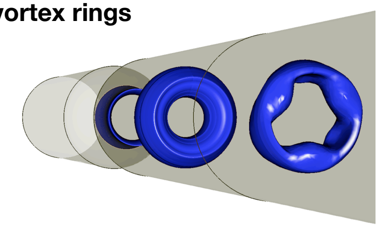
In pulsatile flow, the dominant flow features are vortex rings associated with pulsing, and shear layers that trail behind them when the pulse period lengthens. The vortex rings have at least two kinds of absolute global instability, while the shear layers can be susceptible to convective instability.

Alternate tilting of successively generated vortex rings is one kind of absolute instability. The pair of images below, obtained one pulse period apart when the flow has reached its asymptotic turbulent state for *Re*=400, dimensionless pulse period 2.5, Womersley number=15.85, illustrate the alternating tilting of vortex rings (blue, drawn as an isosurface of the discriminant of the velocity gradient tensor), and their rapid and energetic breakdown shortly downstream (emphasised by red/yellow isosurfaces of axial vorticity component).

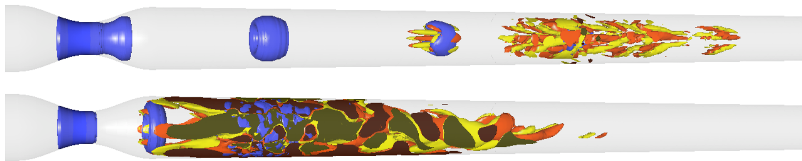


Pulsatile inflow: wavy instability of vortex rings

Wavy vortex-core instability is another kind of absolute instability, which tends to occur at shorter pulse periods. As can be seen to right, the instabilities appear related to Windnall instability of isolated vortex rings, although here they appear at lower azimuthal wavenumber, *k*=3 or 4.



The three- or four-fold symmetry of the instability remains dominant in the turbulent asymptotic states that are obtained at Reynolds numbers near transition. As is the case for the vortex-tilting instability, there is a localised turbulent breakdown that evolves slowly upstream to lie close to the stenosis. The two frames below illustrate a stage in the evolution, and the asymptotic state.



Sherwin & Blackburn (2005) *J Fluid Mech* **533**: 297-327, Blackburn & Sherwin (2007) *J Fluid Mech*, in press.