Steady and pulsatile flow through a locally constricted tube

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Flows, both steady and pulsatile, through a circular tube with an axisymmetric blockage of varying size are studied experimentally and numerically. The geometry consists of a long straight tube and a blockage which is semi-circular in cross-section. This geometry is selected as an idealized model of a stenosed artery. The stenosis has been simplified to a single-parameter blockage, the aim being to highlight fundamental behaviours of constricted flows. The chosen Reynolds numbers (Re), defined using the average inlet velocity and unblocked tube diameter, are in a range relevant to blood flows in the larger arteries. Recent work[1] has shown the outlet length to be an important parameter, particularly for the onset of instabilities in pulsatile flow. The experiments and simulations have been designed to remove, as far as possible, the effect of outlet length on the flow downstream of the blockage. Experimentally, a water flow is considered inside a tube of 19 mm diameter, which has an unblocked length of 2 m both upstream and downstream of the blockage. The flow is characterised using dye visualisations and Particle Image Velocimetry. These results are complemented by spectral-element numerical simulations.

At low Reynolds numbers, the flow is steady and characterised by a jet emanating from the constriction, surrounded by an axisymmetric recirculation zone, the length of which increases linearly with Reynolds number. Figure 1 shows the streamlines and vorticity field from an axisymmetric simulation, at Re = 100 and blockage by area of 75%. The work of Sherwin and Blackburn[1] on the flow through a similar geometry with the same reduction in area showed that the jet loses axisymmetry at a critical Reynolds number of 722. Results from our numerical simulations indicate a similar stability threshold for the present geometry, a transition we aim to qualify experimentally. The effect of a variation in blockage size on the onset and mode of instability is investigated, revealing a change in the azimuthal mode number as the blockage size is decreased. The transition to a time-dependent state at higher Reynolds numbers, downstream of the blockage, is also studied.

The second part of the study looks at flows subject to a pulsatile inlet condition, which more closely describe the type of flow found in the cardio-vascular system. We characterise the stability of such flows, focusing particularly on the effect of the blockage size on any loss of flow-axisymmetry or transition to turbulence.

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[1]Sherwin and Blackburn, *J. Fluid Mech.* **533**, 297 (2005).

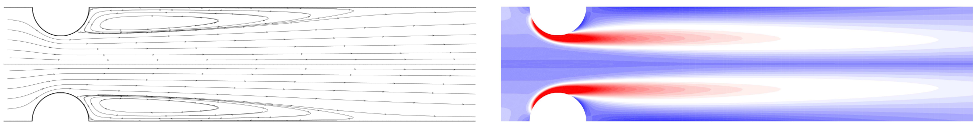

Figure 1: Streamlines and vorticity of the steady flow, at Re = 100 and 75% blockage.