Travelling wave solution with a Λ-vortex pattern in plane Poiseuille flow

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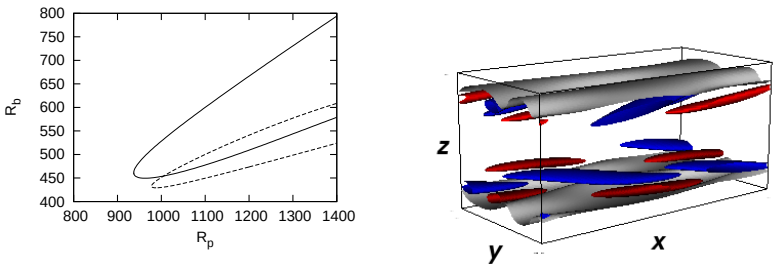
ABSTRACT

A new class of travelling wave solutions with a Λ-vortex pattern is found in plane Poiseuille flow by continuing the stationary and travelling hairpin-shaped fluid vortices found in plane Couette flow [1]. The solutions arise from a saddle-node bifurcation at a Reynolds number that is smaller than the critical value known to date [2] (see Figure 1(a)). As seen from Figure 1(b), in contrast to Waleffe's solution[2] which was obtained from Nagata's solution [3] in plane Couette flow by homotopy, the present solution is characterized by two quasi-streamwise low-speed streaks in one spanwise period $(-\pi/\beta \leq y \leq \pi/\beta)$ in the vicinity of each boundary. The low-speed streaks are alined with the planes of mirror symmetry, $y = \pm\pi/(2\beta)$, with their width varying in a varicose fashion in the streamwise direction. A pair of quasi-streamwise vortices forms a Λ-shaped vortex: vortices are up-lifted downstream while keeping their feet in the neighboring varicose bulges of the streamwise low-speed streaks.



(a) (b)

Figure 1: (a):The Reynolds number, R_p, vs. the bulk Reynolds number, R_b, for the wavenumber pair (α, β) which give the minimum value for R_p. The solid and dashed curves correspond to the present solution and Waleffe's solution [2], respectively. (b):The flow pattern of the present solution at $(R_p, \alpha, \beta) = (937.1, 1.47, 3.06)$. Iso-surfaces of the streamwise velocity at $u = 300$ (gray), and the streamwise vorticity at $\omega_x = 400/-400$ (red/blue).

REFERENCES

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