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Bent pipes: transition and turbulence

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A number of different aspects of the transitional and turbulent flow in bent pipes are discussed, obtained using numerical simulations. This flow is characterised by the appearance of a pair of so-called Dean vortices, which arise due to the action of the centrifugal force in the bend. We start with studying the stability properties of the toroidal pipe, where we show that the flow even for very small curvatures δ is in fact modally unstable [1]. When increasing the Reynolds number, the flow in a torus at low curvature goes through an interesting region where the measured pressure drop is in fact lower than for a straight pipe with the same bulk flow rate, and at times even lower than the laminar (steady) flow; we refer to these states as substraight and sublaminar drag. Finally, when further increasing the Reynolds number, the fully turbulent regime [2] is reached. In this parameter regime, the so-called swirl switching, *i.e.* the periodic dominance of one Dean cell over the other, has been observed in experiments. We will use our numerical simulations to contribute to the understanding of the swirl switching. In particular, based on proper orthogonal decomposition (POD) we can clearly show that the bend induces a travelling wave, which is then in turn responsible for the swirl switching.

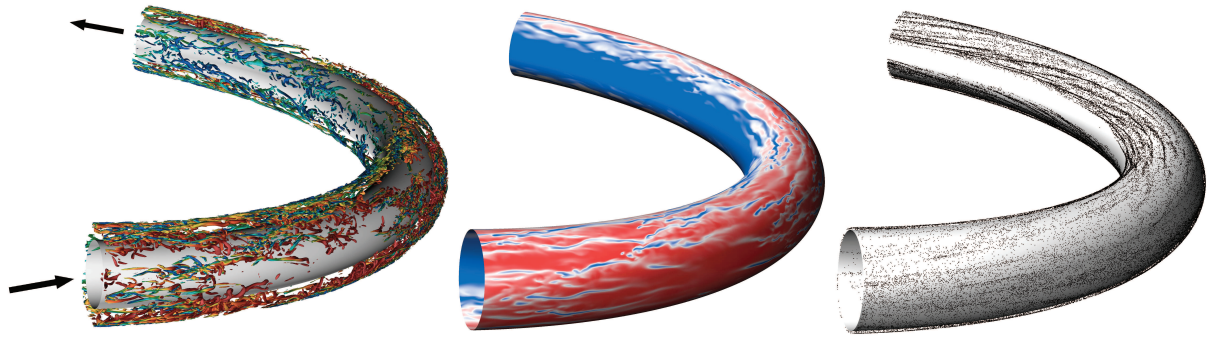

Figure 1: Turbulence in a bent pipe: The pictures show from left to right: Vortical structures in the near-wall region, coloured with the streamwise velocity; the wall-shear stress indicating partial laminarisation at the inner bend; particle distribution for inertial particles. For all simulations $Re_\tau = 360$, curvature $\delta = 0.1$.

REFERENCES

[1] J. Canton, P. Schlatter and R. Örlü. *J. Fluid Mech.*, 792 (2016), 894–909.

[2] L. Hufnagel, J. Canton, R. Örlü, O. Marin, E. Merzari and P. Schlatter. *J. Fluid Mech.*, 835 (2018), 86–101.