Turbulence in a Gradual Expansion Circular Pipe Flow

Kamal Selvam[1], Jorge Peixinho[1] & Ashley P. Willis[2]

[1] Laboratoire Ondes et Milieux Complexes, CNRS & Université du Havre, Le Havre, France
[2] School of Mathematics and Statistics, University of Sheffield, Sheffield S3 7RH, UK
kamal.selvam@univ-lehavre.fr

The flow through a circular pipe with a sudden or gradual expansion experiences transition from laminar to turbulence after a symmetric breaking bifurcation. The recirculation region, which appears due to flow separation and reattachment, is initially symmetric. As the Reynolds number, Re, is increased, the length of the recirculation grows linearly [1] and then becomes asymmetric. Here Re is defined as $Re = Ud/\nu$, where d is the inlet pipe diameter, U is the bulk velocity and ν is the kinematic viscosity. The results of three dimensional numerical simulations of the Navier-Stokes equations are presented for a circular pipe with an expansion ratio $D/d = 2$, where D is the outlet pipe diameter. The length of the diverging section is d. At the inlet, a parabolic velocity profile is applied along with a crosswise perturbation that has an amplitude of 0.001. The idea of adding the perturbation [2] to the numerical system is to resemble as a source of the imperfections that arise in an experiment which comes from many other sources. This perturbation imposes a asymmetry growth in the flow, such that the recirculation region experiences a biased growth. As Re is increased the asymmetry in the flow grows linearly. Prior to the point of transition to turbulence, i.e., $Re \simeq 1680$, the recirculation region oscillates due to shear layer instability. This oscillation occurs in a very narrow range of Re and it also depends on the amplitude of the perturbation [1,3]. At higher Re, the recirculation region breaks into turbulence due to the nonlinear effect, which get localised spatially at $z \simeq 10d$ from the diverging section. Simulations have also been carried out to assess the transient nature of the localised turbulence which indicate that there is no hysteretic behaviour. Moreover the decay time after sudden Re reduction is linear. Finally, the spatial correlation of the streamwise velocity reveals the existence of modes that dominate the flow.

Références

1. C. D. Cantwell, D. Barkley, H. M. Blackburn, *Transient growth analysis of flow through a sudden expansion in a circular pipe*, Physics of Fluids **22**, 034101 (2010).
2. E. Sanmiguel-Rojas, T. Mullin, *Finite-amplitude solutions in flow through a sudden expansion in a circular pipe*, Journal of Fluid Mechanics **691**, 201-213 (2012).
3. O. Marquet, D. Sipp, J. M. Chomaz, L. Jacquin, *Amplifier and resonator dynamics of a low-Reynolds-number recirculation bubble in a global framework*, Journal of Fluid Mechanics **605**, 429-443 (2008).