TRANSIENTS STATES IN THE TRANSITION TO TURBULENCE IN CHANNELS

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Summary: The transition to turbulence in channels of rectangular section (plane Poiseuille flow) is studied following the dynamics of two variables: the mean flow distortion and the turbulent transversal fluctuations. Transitions of the flow are presented in an experimental phase state diagram, which are compared with the predictions of a recent model of D. Barkley, which coupled nonlinearly, equations for these two variables.

Transition to turbulence in channels of rectangular section with plane Poiseuille flows, undergoes a sudden transition to three-dimensional turbulence at Reynolds number between 1000 and 2000, despite the fact that theoretical analysis shows that it is linearly stable, in the regime in which transition occurs[1].

This communication presents an experimental study of the subcritical transition to turbulence of a plane Poiseuille flow. The experiments are performed in a dedicated water channel in our laboratory[2]. The development section is 1 m long and the test section is 1.2 m long. Its cross section is 20 x 150 mm^2. The flow is submitted to very well controlled perturbations, by injection of water through small holes in the upper plate. As this, continuous or transient streamwise vortices are induced as perturbation by jets in crossflow. With Particle Image Velocimetry (PIV), we measure, simultaneously, the transverse and the streamwise components of the velocity. Measurements of many snapshots in lateral planes, at different streamwise stations in the end of the channel and repeated in more than 10 transversal planes, provide good information on the flow state (Figure 1).

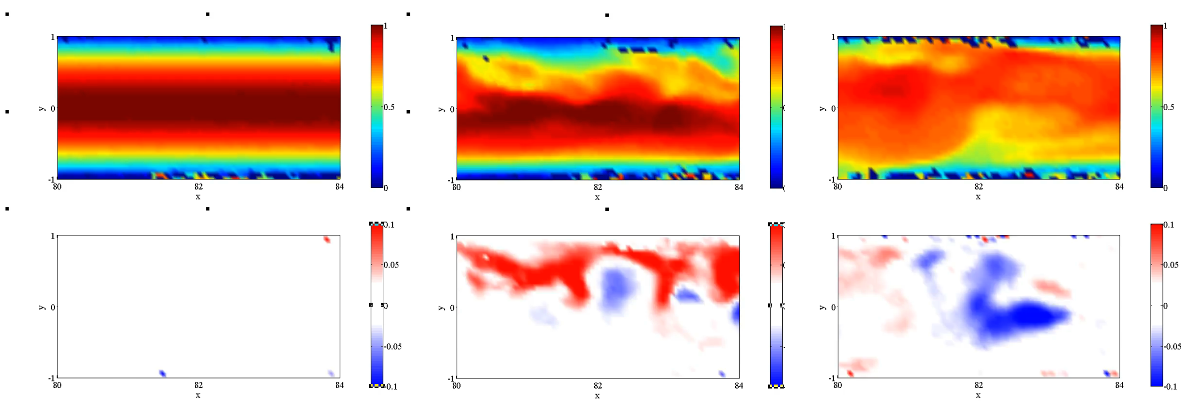

Figure 1: Instantaneous maps of the longitudinal Vx (upper figures) and transversal Vy velocity (lower figures), taken on a lateral portion at the end of the channel. The flow goes from left to right and the experiments are performed at a Reynolds number of 2150. The three pairs of pictures correspond to the flow is in a laminar state (left), intermittent state (center) or turbulent state (right), when the amplitude A of the continuous perturbation (A = ratio of the injected velocity to the channel velocity) is A = 0,11, A = 0,29 and A = 1,16 respectively. These measurements are obtained in the plane of the axis of one central jet of the actuator.

Owing to this information, the mean flow modification measured with the centerline velocity (u) and the magnitude of the transversal turbulent roll fluctuations (q) are obtained. The dynamics of the transition is described following the trajectories of the flow states of these u and q variables, in an experimental phase space. The results of the observed states were obtained for different amplitudes of the continuous forcing or for different duration of the external perturbation, in the explored range of Reynolds number values from 1000 to 5000. The analysis of these trajectories will allow obtaining the fixed points of the dynamics of the experimental system.

Different nonlinear models for subcritical transition to turbulence have been proposed in the last years. Most are Galerkin truncations and reduced variable dimension models of the full flow equations [3-4] or phenomenological amplitude equations, for the amplitude of the fluctuations [5]. A recent model, proposed by Barkley [6], is based on coupled amplitude equations for a local variable as the transversal turbulent roll fluctuation (q) and a global variable as the centerline velocity (u), which is the measure of the mean flow distortion.

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One of the goals of this experimental work is to test these nonlinear evolution models for the turbulent fluctuations and global flow parameters, during the subcritical transition. Our experiments showed correspondence between the experimental phase space and the predictions of the Barkley model and emphasize the underlying physics of the coupling of a global parameter -the mean flow distortion- modified by the nonlinear contributions of the local velocity fluctuations of the turbulent coherent structures. We are capable to identified coefficients of these models, which would lead to actual quantitative predictions of the dynamics of real situations in channel flows.

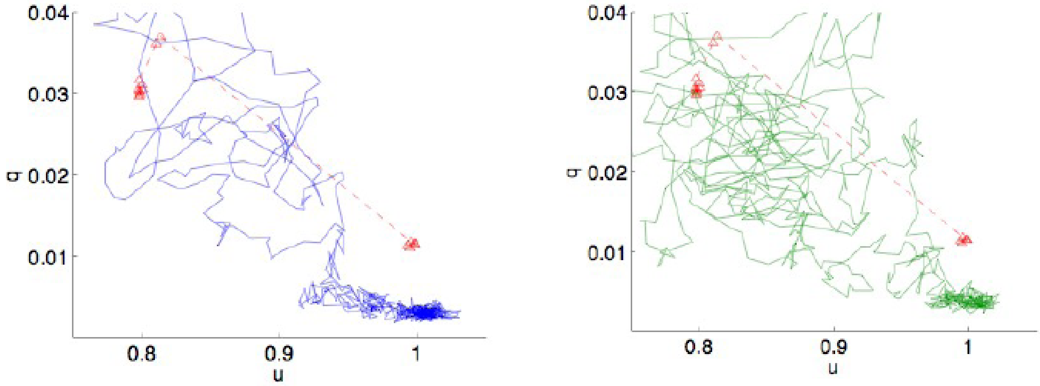

Figure 2: Experimental phase space, obtained from measurements of the velocity field (centerline velocity u and the transversal fluctuation q) with time-resolved PIV at f = 250 Hz. The experiments correspond to conditions of transient forcing with crossflow jets at Re = 2500, for two different forcing. One forcing during T = 50 msec (left) and the other, during T = 1sec (right). The transient perturbation induces puffs and slugs. The red points show the fixed points (laminar and turbulent) under continuous forcing.

References

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