Interaction between structures in a Couette-Poiseuille flow

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In the transition regime, active turbulence is localized in turbulent spots in wall-bounded shear flows, which are for instance flows between two parallel plates. They contain coherent structures, such as streamwise vortices called rolls and modulations of the streamwise velocity called streaks. Many theoretical and numerical works have shown that the nonlinear interaction between these structures is responsible for the self-sustaining process (SSP) of the turbulence, but experimental studies are scarce. We investigate experimentally the interaction between these coherent structures using two sets of experiments.

We perform the experiments in a plane Couette-Poiseuille channel in which the flow is driven by a moving belt and connected to two reservoirs so that the mean flux is zero (fig. 1A). The direction of the moving belt defines the streamwise direction x, z is the spanwise direction and y the wall-normal direction. The streaks are quantified by the streamwise velocity fluctuations u_x, and the rolls by the spanwise velocity u_z and by the wall-normal velocity u_y.

In the first set of experiments, we study the decay of turbulence using a 'quench' protocol, i.e. an abrupt decrease of the Reynolds number Re from a fully turbulent state to a laminar regime [1]. We show that the rolls decay faster than the streaks. The streaks have two decay stages in the decay process. During the first stage of the decay, the remaining rolls slow down the decay of the streaks. This is consistent with the lift-up effect, i.e. the formation of streaks by linear advection of the rolls.

In a second set of experiments, we study the waviness of streaks using vortex generators to induce unstable wavy streaks [2]. The evolution of the streaks becoming wavy from a straight state is characterized using stereoscopic PIV, and processed using a new method that we developed. Using spatial Fourier filtering, we define a proxy for the waviness $\langle|\omega_{y,\mathrm{wavy}}|\rangle$. Our experimental results show that the wall-normal velocity, which is a proxy for the rolls, is correlated to the increase of the waviness of the streaks, as expected from SSP models (fig. 1B). Moreover, for streaks of low waviness, the value of $|u_y|$ is small and related to the amplitude of the streak $|u_x|$, as expected for linear lift-up.

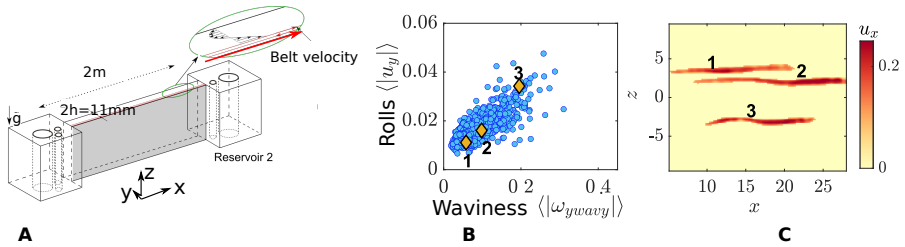

Figure 1. A : schematic view of the experimental set-up. B : link between rolls and waviness, a point corresponds to the average on a streak. C : corresponding streaks for the three points indicated in B.

Références

1. T. Liu, B. Semin, L. Klotz, R. Godoy-Diana, J. E. Wesfreid & T. Mullin, Decay of streaks and rolls in plane Couette-Poiseuille flow, *J. Fluid Mech.*, **915**, A65 (2021).
2. T. Liu, B. Semin, R. Godoy-Diana & J. E. Wesfreid, Lift-up and streak waviness drive the self-sustained process in wall-bounded transition to turbulence, *Phys. Rev. Fluids.*, accepted