Dynamics of turbulent structures in Couette-Poiseuille flow

Benoît Semin, Tao Liu, Ramiro Godoy-Diana, José Eduardo Wesfreid

PMMH, CNRS, ESPCI Paris, Université PSL, Sorbonne Université, Université Paris Cité, F-75005, Paris, France
benoit.semin@espci.fr

Laminar and turbulent regions can coexist in the transition regime in wall-bounded shear flows, which are for instance flows between two parallel plates. In this regime, active turbulence is localized in turbulent spots, which contain coherent structures, such as streamwise vortices called rolls and modulations of the streamwise velocity called streaks. The nonlinear interaction between these structures is responsible for the self-sustaining process (SSP) of the turbulence. We investigate experimentally the dynamics of these structures and the detailed interplay of their components.

We carry out the experiments in a plane Couette-Poiseuille channel in which the flow is driven by one 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 and rolls are quantified respectively by the streamwise velocity fluctuations u_x and u_z, measured using particule image velocimetry (PIV). 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.

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.

We also study the noise effect, which is the external disturbance generated by the belt driving cylinder, on the transient decay and the permanent regime. The decay dynamics is independent of the noise level. The noise shifts the apparent critical onset of transition. We use the susceptibility of the spanwise fluctuations u_z in the permanent regime to quantify the noise intensity.

We study the waviness of streaks using vortex generators to induce unstable wavy streaks. The evolution of the streaks becoming wavy from a straight state is characterized using stereoscopic PIV. We apply a spatial filter to separate the straight part and the wavy part of the flow (fig. 1B). Our experimental results show clearly how the appearance of the spanwise velocity and the wavy wall-normal velocity is correlated to the increase of the waviness of the streaks, as expected from SSP models.

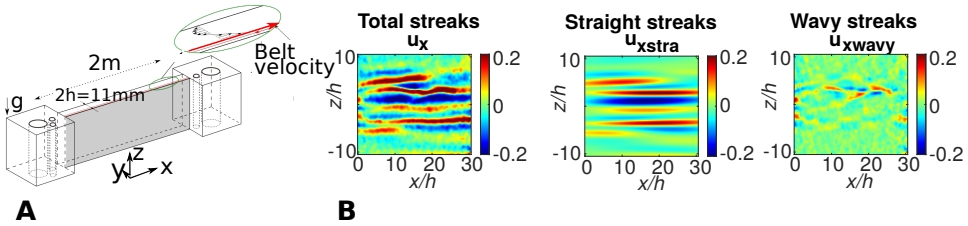

Figure 1. A : sketch of the experiment. B : streamwise fluctuation velocity u_x, made dimensionless using the belt velocity, at Re=500 and spatial filtering separating the straight and wavy components of the streaks.

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).