Transition to turbulence in plane Couette-Poiseuille flow with external noise

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The transition to turbulence in many confined shear flows, like plane Couette flow and circular Poiseuille flow, is characterized by the coexistence of laminar and turbulent regions. We have built such a water channel where one wall is fixed and the other is a moving belt: a plane Couette-Poiseuille flow with a zero mean flux [1]. The Reynolds number of this setup is defined as $Re = U_{belt}h/\nu$, where U_{belt} is the belt velocity, h is the half channel width with $2h = 11$ mm and ν is the kinematic viscosity of water. The aspect ratio is $L_x/h = 390$ along streamwise direction and $L_z/h = 90$ along spanwise direction.

We determine the critical Reynolds number Re_c by decreasing Re from a fully turbulent state ($Re = 1000$) to a lower Re [2]. Fig. 1*a* shows $2D$ streamwise velocity U_x snapshot after high-pass spatial filtering to remove large scale flows. The life time of turbulence τ is defined as the first time where the streamwise energy E_x decreases to 10% of initial energy (see Fig. 1*b*). In Fig. 1*c*, we can observe that the inverse of this life time τ^{-1} decreases proportionally to $Re_c - Re$ with $Re_c = 650$. This is similar to the observation for pipe flow [3] and plane Couette flow [4]. Turbulent spots are advected through the channel from the side tank, modifying the averaged amplitude in the permanent state after the transient decay. We have checked that Re_c is independent of this external noise by reducing it with grids installed at the entrance of the channel ('low noise' in Fig. 1*c*). This shows that Re_c is an intrinsic property of the flow.

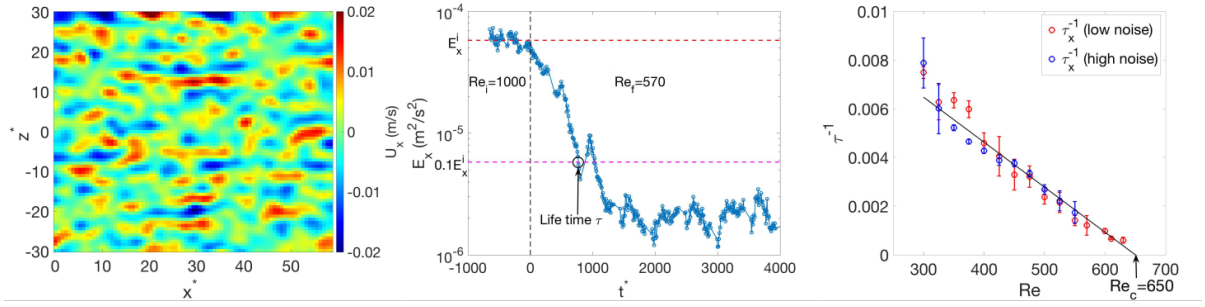

Figure 1. (a) Snapshot of 2D streamwise velocity field U_x measured by PIV with high-pass spatial filtering at $Re = 1000$ measured in xy plane at y position where streamwise velocity is nearly zero in laminar state. (b) Temporal evolution of the streamwise energy E_x for $Re_f = 570$. (c) Inverse of life time τ^{-1} as a function of Reynolds number for two different noise levels; error bars: standard deviation of 5 realizations.

References

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