Transient states in plane Couette flow

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Résumé

In spite of their geometric simplicity, confined shear flows experience a complex transition to turbulence which is a direct consequence of its subcritical nature. If this transition is one of the oldest remaining open problems in mechanics, understanding it better could also pave the way to original control strategies. Close to transition threshold, turbulent patches involve many time and space scales leading to a complex dynamics. As turbulent structures move at speed close to that of the mean flow, most of the existing experimental set-ups do not allow long time scale studies. This is why we have designed a plane Couette flow for which, as the mean velocity is zero, we can observe and analyze turbulent structures for arbitrary long times. Measures are performed with a high spatial resolution Particle Image Velocimetry (PIV) system that also resolves all the turbulent time scales.

Our study is dedicated to the transitional regime where turbulent and laminar states coexist in the physical space. We aim at characterizing the steady states (if they exist) in this transitional regime. To do so, we prepare the plane Couette system in a homogeneously turbulent state at an initial Reynolds number R_i=480 and then, we decrease the Reynolds number at a given rate ΔR/s down-to a final Reynolds number R_f . The fraction of the physical space which is turbulent (the so called turbulent fraction) is computed as a function of time to allow a global monitoring of the complex dynamics. Because our protocol consists in a monotonous decrease of the Reynolds number, we expect the resulting turbulent fraction to be also a decreasing function of time. Note that most of our experiments are conducted on long times, typically several thousand advection times. We raise the following questions: (i) is the system relaxing to a given asymptotic state, and if yes, what does this state depend on (R_f, ΔR/s...)? (ii) Regardless of the possible asymptotic state, what are the characteristics of the dynamics leading to it?

The two control parameters of our system are varied in a wide range: R_f is set from 300 below which turbulence cannot be sustained to 410 above which the flow is homogeneously turbulent; ΔR/s is tuned from 0.3 to 1000. The latter actually correspond to a quench of the system while the former can be considered as an annealing. We show that an asymptotic state seems to be reached by each experiment and that this state seems to only depend on R_f at least when considering the turbulent fraction. The dynamics nevertheless does depend on ΔR/s. Particularly, we show that in roughly one experiment out of two, the dynamics slows down on transient states for which the turbulent fraction is constant. These states are associated with given turbulent fractions (namely 5%, 10%, 30% and 50%) around which the system fluctuates for arbitrary long periods of time before relaxing to the lower turbulent

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fraction asymptotic states. We provide a full characterization of these transient states and we raise questions on their very nature, particularly on their links to the phase space topology. We consider this last point as a leading priority for the coming years.

Mots-Clés: Particle Image Velocimetry, annealing, quench, phase, space topology, subcritical transition to turbulence