Bifurcation from/to turbulence in wall bounded flows: Decay of turbulent bands and growth of turbulent spots in plane Couette flow

P. Manneville
Hydrodynamics Laboratory, École Polytechnique, 91128 Palaiseau, France
e-mail: paul.manneville@polytechnique.edu - Web page: http://www.ladhyx.polytechnique.fr/

ABSTRACT

In wall-bounded flows, the globally subcritical character of the bifurcation results in attractor coexistence *in phase space*. One of the attractors is the *laminar* flow and the other some nontrivial state in phase space, called *chaotic* or *turbulent* according to whether the aspect ratio of the system is small or large. This coexistence takes place in a range of Reynolds numbers $R \in [R_{\rm g}, R_{\rm t}]$, the lower bound of which, $R_{\rm g}$, is the global stability threshold below which laminar flow prevails in the long time limit. Provided that the aspect ratio is sufficiently large, the laminar/turbulent coexistence between $R_{\rm g}$ and $R_{\rm t}$ develops *in physical space*. Above $R_{\rm t}$ turbulence is essentially space-filling.

Here we focus on the dynamics of plane Couette flow around $R_{\rm g}$ and first study the fragmentation and decay of the experimentally-observed oblique turbulent bands, using direct numerical simulations in systems extended enough for several bands to exist [1]. We point out a two-stage process involving the rupture of a band and next its slow shrinking. Both processes are attributed to *transient chaos* taking place at the scale of the *minimal flow unit* (MFU). Band opening stems from large deviations (rare events) of the so-generated stochastic process, while the slow retreat results from the local dynamics at the extremities of a band segment, statistically speaking [2]. Upon increasing R, local withdrawal is converted into local growth – still at the statistical level – but the possibility of rare turbulent collapse remains so that, for $R_{\rm g} \lesssim R$, the growth of a turbulent spot issued from a germ of sufficient size is still problematic. Global growth occurs when the contamination by turbulence inside the spot outweighs the chance of turbulence collapse over a sizeable part of it. The set of probabilities involved depends sensitively on the value of R (see [3] for a parallel study in a quasi-1D, spanwise oriented configuration). Large scale flows generated outside the spot by Reynolds stresses in the interior of the turbulent region are also seen to play a nontrivial role that is currently under study.

The general character of these qualitatively well-identified processes should motivate a fully quantitative study of their statistics. An extreme variety of possible evolutions however results from the interplay of dynamics at local (MFU), intermediate (spot diameter/band width), and global (mean flow) scales. Beyond the few cases that have served to point them out, this renders such a study computationally rather expensive. Because it depends on spanwise and streamwise coordinates, the situation is indeed much less tractable than the case considered in [3], even if it is closer to the experiments.

REFERENCES

[1] Paul Manneville *On the decay of turbulence in plane Couette flow* Fluid Dynam. Res., submitted, preprint available from the author

[2] Joran Rolland & Paul Manneville *Pattern fluctuations in transitional plane Couette Flow* J. Stat. Phys. **142** (2011) 577–591

[3] Yohann Duguet & Philipp Schlatter *Stochastic motion of a laminar/turbulent interface in a shear flow* 13th European Turbulence Conference, Warsaw, 2011