Wavelength selection in transitional turbulence

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The transition to turbulence in plane shear flows is characterized by coexisiting turbulent and laminar zones [3]. Unlike in the case of pipe flow [1], these zones appear in the form of regular patterns, oblique in the streamwise-spanwise plane. The mechanism explaining how those statistically steady structures arise from uniform turbulence is still unclear: is it due to a random nucleation of laminar gaps; or to a long-wavelength instability of the uniform turbulent flow?

We first address this question by using periodic domains of restricted lengths and fixed tilt, where patterns of fixed wavelengths can exist, over a limited range in Reynolds number. The stability of such fixed-wavelength patterns is studied as a function of Reynolds number, showing that there is a prefered wavelength (around 40 half-gaps) for which the pattern is most stable.

This picture is complemented by a study of the energy balance of patterns in a restricted-sized periodic domain, with a varying wavelength. We show that the most stable wavelength corresponds to a most energetic state, which is characterized by a strongest mean flow.

We secondly study the impact of the mean flow along those turbulent bands. We therefore introduce a Modified Plane Couette flow, in which the large-scale spanwise velocity is suppressed, while still allowing modulations of the streamwise velocity, necessary for the existence of bands. We show that in the absence of large-scale spanwise flow, laminar gaps appear at random locations in space and time (like the puffs in pipe flow). This suggests that the regular patterned appearance of gaps is related to large-scale spanwise flow but not essential to the evolution of bands in Plane Couette Flow.

This work is partially supported by a grant from the Simons Foundation (Grant number 662985, NG).

References

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