Thesis subject 2017

Laboratory: Physique et Mécanique des Milieux Hétérogènes, UMR 7636

University: UPMC Paris 6

Title of the thesis: Transition to turbulence in shear flows

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Collaborations within the thesis University of Warwick and Université de l’Havre

Program affiliation: ANR Turboflow

Cotutelle:

University:

This subject can be published on the doctoral school’s web site: yes

Thesis’s summary (abstract):

Transition to turbulence remains an open problem, even in simple geometries. In confined shear flows, for example flows between parallel walls, this transition is subcritical. In the transition regime, turbulence is localized in turbulent spots, surrounded by laminar flow. These turbulent spots contain coherent structures, like rolls and modulations of the streamwise flow. Similar structures are found in boundary layers. The objective of this PhD thesis is to study the interactions between these structures and how turbulence is sustained by these interactions. The starting point is an existing experimental setup of a Couette-Poiseuille flow, which allows one to obtain precise measurements of the spatio-temporal patterns of the turbulence. The structures will be extracted from the flow velocity, and their interactions compared to theoretical dynamical models.
Subject: Transition to turbulence in shear flows

Confined shear flows are flows between two parallel plates or in a tube. In these flows, the transition to turbulence is subcritical: the flow may be laminar or turbulent for the same Reynolds number, depending on an initial perturbation.

In the transition regime, turbulence is localized in turbulent spots, surrounded by laminar flow. These spots are elementary “building blocks” where the turbulence is sustained, and their dynamics gives insight about the mechanisms of turbulence. The velocity field of these spots is partly composed of random fluctuations, but it also contains coherent structures, such as rolls, streaks (spanwise modulation of the streamwise velocity). Similar structures are found in other configurations, in particular in boundary layers.

The objective of this project is to determine how the interactions between these structures sustain the turbulence, and induce the evolution of the spots.

Left: turbulent spot surrounded by laminar flow. Right: detail of a wave-like structure in a turbulent spot.

We have recently setup an experiment to study these turbulent spots [1]. It consists of a Couette-Poiseuille flow, i.e. of two parallel walls, one moving and the other fixed. Since the turbulent spots move with a velocity close to the mean velocity, which is zero in this setup, they can be measured for long duration of time. This is relevant because the evolution of the spot is slow. This setup is one of the few designed worldwide to study the transition to turbulence in shear flows.

This existing setup (moved to the Jussieu campus in Nov. 2017), will be the starting point of the PhD thesis. The next step will be to improve the velocity measurements, using stereo-PIV and 3D PIV (particle image velocimetry). Other sensors, such as pressure sensors, will be used to acquire global and high frequency data.
These extensions are required to fully characterize the flow and the structures it contains. The experimental setup will be then modified to study the effect of roughness, whose role close to the transition is an open problem.

The velocity field will be analyzed, and the structures it contains will be extracted, using for instance Fourier decomposition and filtering and mode extraction like dynamic mode decomposition. The interaction between these structures will be characterized, using the correlations in the time evolution and the variation with the Reynolds number.

We also aim at determining whether the interaction between the different structures in the spots, like rolls and streaks, can be described by a simple nonlinear dynamical model, as predicted theoretically.

This PhD thesis will benefit from collaborations with theoreticians and numericists.