VELOCITY AND FRONT VELOCITY MEASUREMENTS IN EXPERIMENTAL PLANE COUETTE FLOW

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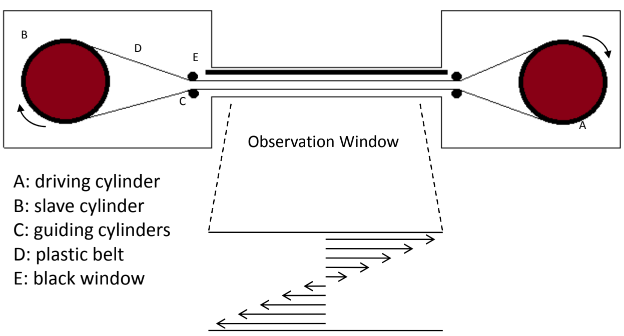
Abstract We have designed a new experimental plane Couette flow in order to investigate the turbulent-laminar coexisting regimes appearing along the sub-critical transition to turbulence in this geometry. We present the phase diagram of this new experiment that is in the line of the previous setups. Particle Image Velocimetry (PIV), Laser Doppler Anemometry (LDA) and visualisations coupled with refined image processing algorithms are used to characterise the laminar-turbulent boundaries around growing turbulent spots and stable turbulent patterns.

INTRODUCTION

Plane Couette flow belongs to the class of shear flows. It is linearly stable for any Reynolds number but it experiences a sub-critical transition to turbulence for moderate values of this control parameter[4, 8]. This transition implies the existence of a wide range of the control parameter values for which turbulent and laminar domains coexist and experience a complex spatio-temporal dynamics [3] that can even take the form of organised oblique stripes patterns living on long time scales[6]. Even if most of these results have been obtained experimentally in the nineties the associated mechanisms are still not understood. This explains the recent renewal of interest for this flow that has led to numerous numerical studies[2, 5, 7].
To date, numerical simulations have enough resolution to solve all the relevant scales even if simulation times are still a limiting factor as long as many runs have to be done. Nevertheless, due to the nature of the observed phenomenon, a statistical approach implying large sets of data seems relevant but is only accessible experimentally. That is why we have built and instrumented a new experimental setup in order to study laminar-turbulent coexistence from a quantitative point of view.

EXPERIMENTAL SETUP AND PHASE DIAGRAM

The plane Couette flow ideally takes place between two infinite plates moving at the same velocity in opposite directions. Experimentally, this can be achieved by rotating a belt as sketched in Figure. 1 when the gap is small as compared to the other dimensions. According to the bifurcation diagram of Couette flow as obtained in the nineties [4, 8, 6], we



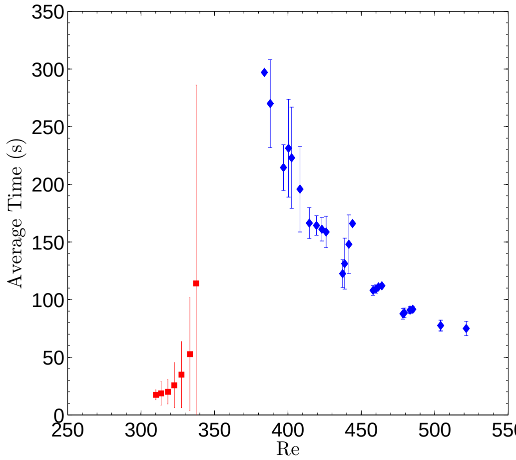


Figure 1. Left: sketch of the experimental setup. Right: averaged time to observe a fully turbulent or fully laminar flow during a cold start or a quench experiment respectively as a function of the final Re. See text for details.

can define three critical Reynolds numbers. Under Ru, turbulence is never sustained, however strong is the perturbation brought to the flow. Between Ru and Rg, turbulence is transient, but its lifetime increases when Re approaches Rg from below. Above Rg turbulence takes the form of irregular spots that progressively merge to form oblique stripes when approaching Ru. Above Rt, a featureless turbulence regime is observed. We present the bifurcation diagram as obtained in our experiment that compares well to the earlier cited results. In order to determine these thresholds, we have performed quench experiments for which Re is suddently decreased from a fixed value above Rt to values below Ru and cold start experiments for which Re is suddently increased from 0 to values above Rt. In both cases, we have recorded the time required for the flow to be fully laminar or fully turbulent respectively. From an experiment to another, these times are widely distributed. Their mean at constant final Re is diverging when getting close to Ru or Rt allowing the determination of these critical values (see Figure. 1). For values of Re between these thresholds, coexistence of turbulent and laminar domains is observed. The fraction of the flow which is turbulent (F_t) depends on the Reynolds number and does not goes continously to 0 when approaching Ru due to the sub-critical nature of the transition.

VELOCITIES AND FRONT PROPAGATION MEASUREMENTS

Our experiment has been instrumented with a two-component Laser Doppler Anemometry (LDA), a Particle Image Velocimetry (PIV) and a visualisation system. We present the first associated measurements: from the LDA and PIV we have extracted mean flows in order to validate the quality of our setup. PIV data are also used to study streaky structures close to Rt in a wide gap configuration. Visualisations associated to texture detection allows to track laminar-turbulent fronts on time scales long compared to the time required to build or destroy a stripe pattern.

CONCLUSIONS

This poster presents the first measurements performed in our plane Couette experiment. These preliminary results open the way to quantitative statistical analysis of patterns growth and decay in the turbulent-laminar coexistence regime.

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