ROBUST REAL-TIME ESTIMATION OF THE STATE OF THE FLOW PAST A BACKWARD-FACING STEP.

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Abstract Real-time experimental estimation of the state of a separated flow is crucial in the perspective of closed-loop flow control. In this study a classic backward-facing step flow was investigated using real-time flow optics measurements. Different ways to translate large amounts of instantaneous 2D data into actionable local of global scalar quantities are examined. Alternative definitions for classically used quantities to qualify the state of the flow, such as the instantaneous or the mean recirculation bubble length, are introduced. Previous definitions using parietal informations can be expanded upon or modified to integrate two-dimensional and three-dimensional information. Advantages and drawbacks of the different definitions are discussed in the perspective of closed-loop experiments.

INTRODUCTION

Flow separation is a major concern in many industrial applications : turbomachines, wings or bluffs bodies such as cars and trucks. In most cases, flow separation is responsible for lower performances or nuisances (lower lift, higher drag, aeroacoustic noise or flow-induced vibrations).

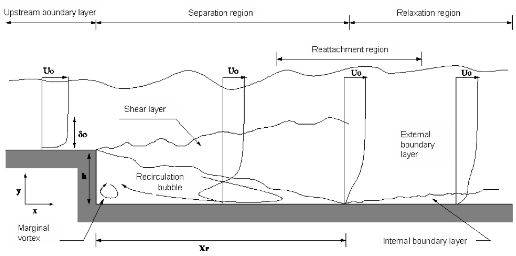

Figure 1: Sketch of the flow downstream a backward-facing step [1].

The backward facing-step (BFS) is the simplest geometry used to study such flows. Despite its simple geometry, the BFS flow shows complex behavior in both space and time. Figure 1 summarizes the main flow features such as the shear layer just downstream the step edge or the large recirculation bubble. Investigations of the flow using parietal (wall shear stress, wall pressure) sensors have yielded a number of quantities, such as recirculation bubble length or the location of the rms pressure peak, used to qualify or control the flow [2, 5, 7]. Advances in measuring technology allow for the online computation of 2D2C (two-components in a plane) velocity fields [4, 6] or offline computations of 2D3C or even 3D3C (measurement of the three-components in a volume) velocity fields [8, 3]. However most experimental quantities used to define the state of a separated flow flow are based on parietal informations, the time-dependant and/or 3D nature of the flow seldom being taken into account.

DISCUSSION

Figure 2a shows an instantaneous 2D longitudinal velocity field downstream a BFS measured and computed in real-time using a standard velocity computation flow optics algorithm [6]. The recirculation bubble length can be computed using velocity profiles close to the wall using traditional criteria. However, most of the time the mean recirculation length is computed on time-averaged smooth velocity fields. Experimental instantaneous data are usually noisy and it is very difficult to precisely estimate the length of the recirculation bubble. Therefore, using a proper criterium, a recirculation bubble *surface* can be defined and computed in real-time as shown on Figure 2b). A typical time-serie of fluctuations of recirculation surface is shown on Figure 3. This instantaneous estimate of the state of the separated flow could be used as an input in a closed-loop experiment.

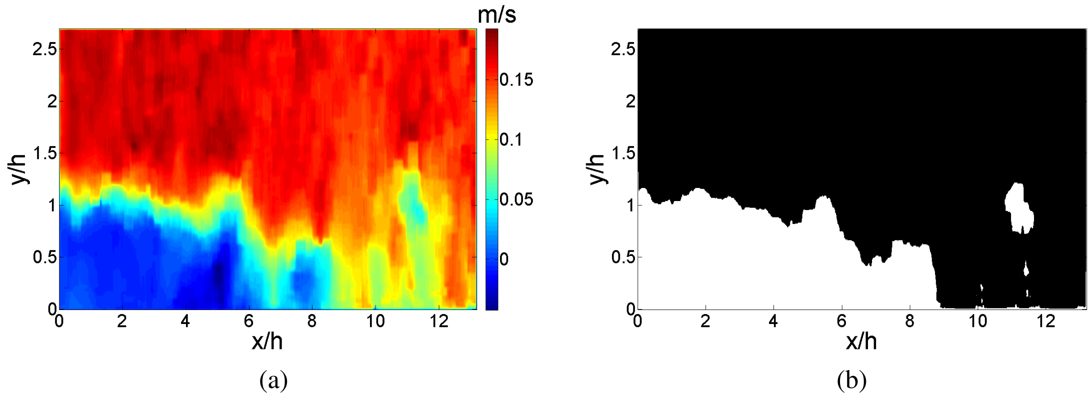

Figure 2: a) Instantaneous longitudinal velocity field of a BFS flow. $X/h = 0$ correspond to the step edge abscissa. b) Estimation of the recirculation bubble surface (white area) using a quantitative criterium on the instantaneous velocity field to define the frontier of the separated flow region.

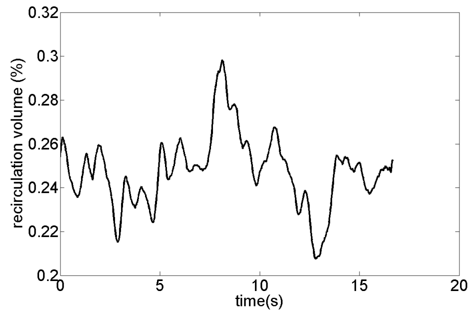

Figure 3: Time-serie of the recirculation bubble surface as a percentage of the 2D velocity field.

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