Influence of porous material on the flow behind a backward-facing step : experimental study

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We investigate effect of porous insert located upstream of the separation edge of a backward-facing step (BFS) in early transitional regime as a function of Reynolds number (Fig. 1a). This is an example of hydrodynamic system that is a combination of separated shear flow with large amplification potential and porous materials known for efficient flow destabilisation. Spectral analysis reveals that dynamics of BFS is dominated by spectral modes that remain globally coherent along the streamwise direction. We detect two branches of characteristic frequencies in the flow and with Hilbert transform we characterise their spatial support. For low Reynolds numbers, the dynamics of the flow is dominated by lower frequency, whereas for sufficiently large Reynolds numbers cross-over to higher frequencies is observed. Increasing permeability of the porous insert results in decrease in Reynolds number value, at which frequency cross-over occurs. By comparing normalised frequencies on each branch with local stability analysis, we attribute Kelvin–Helmholtz and Tollmien–Schlichting instabilities to upper and lower frequency branches, respectively. Our results show that porous inserts enhance Kelvin–Helmholtz instability and promote transition to oscillator-type dynamics (Fig. 1b-c). Specifically, the amplitude of vortical (BFS) structures associated with higher-frequency branch follows Landau model prediction for all investigated porous inserts.

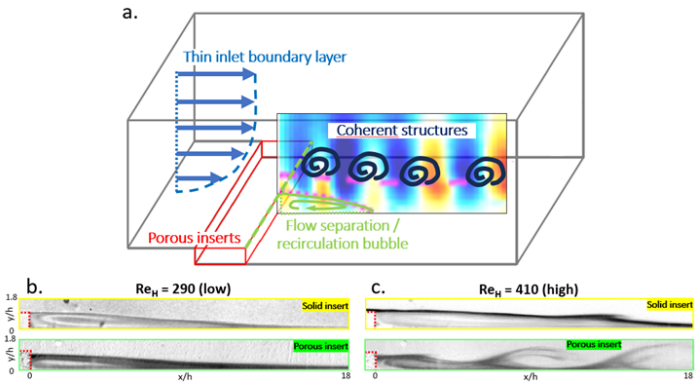

Figure 1. a) schematic representation of BFS configuration under investigation, which includes : thin Blasius boundary layer at the inlet (in blue), flow separation induced by discontinuity of the geometry (in green), porous insert upstream of the separation (in red) ; b) and c) visualisations for low and high Reynolds numbers, from left to right. The solid impermeable reference case (in yellow) and the most permeable porous insert (in green) are presented in the top and bottom rows of panels b-c. The bottom-right panel illustrates roll-up due to Kelvin-Helmholtz instability. Taken from [1].

Références

1. L. Klotz, K. Bukowski & K. Gumowski, Influence of porous material on the flow behind a backward-facing step : experimental study, *J. Fluid Mech.*, **6**, A31 (2024).