Global instabilities of the flow over a forward-facing step

- BIFD 2011 -

Daniel Lanzerstorfer* and Hendrik C. Kuhlmann†

* Institute of Fluid Mechanics and Heat Transfer
Vienna University of Technology
Resselgasse 3, 1040 Vienna, Austria
e-mail: daniel.lanzerstorfer@tuwien.ac.at

† Institute of Fluid Mechanics and Heat Transfer
Vienna University of Technology
Resselgasse 3, 1040 Vienna, Austria
e-mail: h.kuhlmann@tuwien.ac.at

ABSTRACT

The two-dimensional flow of an incompressible, Newtonian fluid over a forward-facing step in a plane channel is considered. The geometry is varied in a quasi-continuous way covering constriction ratios (step to outlet height) from $\Gamma = 0.05$ to $\Gamma = 0.95$.

Assuming the system to be infinitely extended in spanwise direction, a global linear stability analysis reveals that the stability boundaries are continuous functions of the constriction ratio. It will be shown that the critical Reynolds and wave numbers of [2] for $\Gamma = 0.5$ and $\Gamma = 0.25$ are not correct as already mentioned by [1]. However, the present study demonstrates that the results of [1] clearly depend on the grid and on the length of the inlet channel. Moreover, the critical Reynolds numbers for asymptotically long inlet-channel lengths are up to 1.7 times higher than those obtained by [1].

In order to understand the physical nature of the instabilities the kinetic energy transferred from the basic flow to the critical mode is computed. The energy-transfer analysis reveals that all instabilities are based on a combination of the classical lift-up mechanism and flow deceleration.

The observed steady, three-dimensional streaky structure downstream of the step is very similar to the results of the direct numerical simulations of [4] and the experimental findings of [3].

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