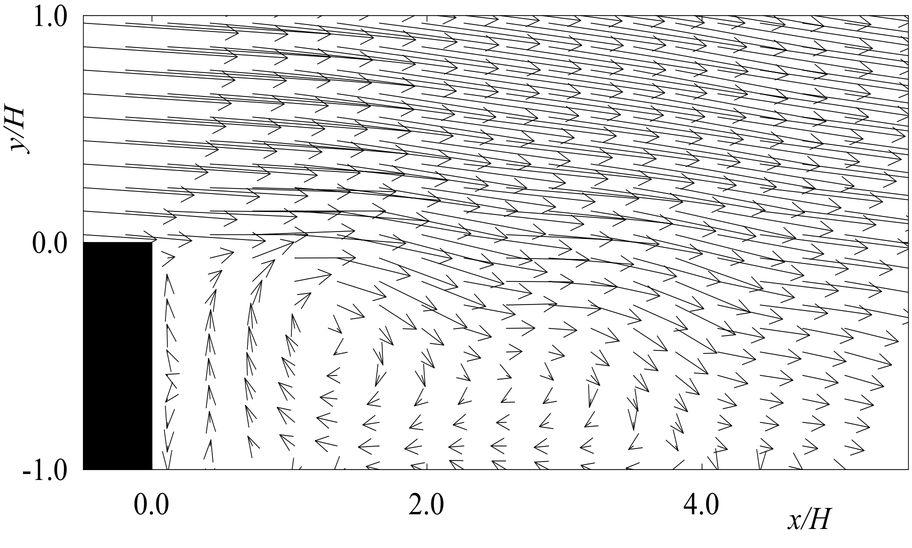
CASE 9.3:
periodically perturbed separated flow over a backward-facing step



Phase averaged velocity field at max. injecting phase

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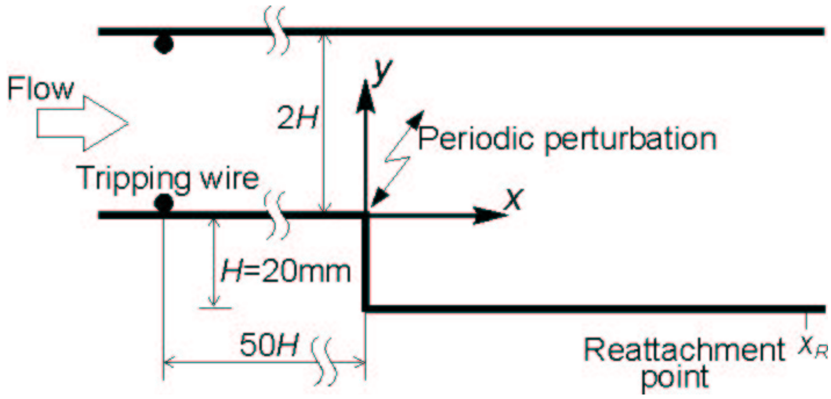

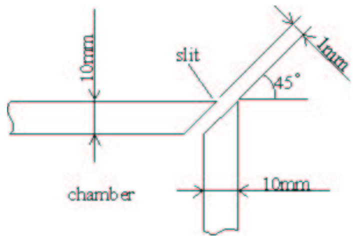

Details around the step edge

Test section

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Important parameters

inlet channel width:	*h*	40mm
step height:	*H*	20mm
expansion ratio:	ER	1.5
Reynolds number:	*Re*	3,700 ($U_c H$/nu)
width of the slit at the step:		1mm
velocity amplitude of the perturbation:	V_{ex}	0.3U_c
non-dimensional perturbation frequency:	*St*	0.08, 0.19, 0.30 ($U_c f/H$)

Results to be submitted

The computers are requested to prepare their results in the format comparable to the available database. The mean velocity and Reynolds stress should be averaged over a period of perturbation. Note that the Reynolds stress obtained by the measurement is the sum of turbulent and oscillatory (periodic) parts. The Reattachment length should also be presented. In particular, the variation of the reattachment length over a period of perturbation should be presented for all conditions except for the steady case.

Outline

The turbulent separating flow over a backward-facing step is perturbed by periodic suction/injection at the step edge. The reattachment length varies as a function of the frequency of imposed perturbation. The reattachment length is reduced at maximum by 30% compared to the steady state. The participants are requested to perform unsteady computations for three different perturbation frequency and to compare the results with the experiment.

Database

Ensemble-averaged velocity components in two directions and three Reynolds stress components are available at some representative channel cross section. Data is stored in a comma-separated-text file: stepdata.csv

Instruction for Participants

The inlet flow condition is a fully developed turbulent channel flow at Re=3,700, with Re being the Reynolds number based on the channel half width and channel center velocity. The participants are advised to perform a computation for inlet channel flow and use the result to specify the inlet condition for the back-step computation. It is advised to use a low-Re turbulence model to keep the spatial resolution, particularly in the region around the slit injection.

The suction/injection of the fluid is made through a narrow spanwise slit. The velocity profile across the slit may be uniform. For those who wish to do something more real, the computation of unsteady, oscillatory channel flow may be conducted to obtain distributions across the slit.

The bulk velocity v_ex at the slit exit is expressed as

$$v_{ex} = V_{ex} \sin\left(2\pi f_{ex} t\right)$$

with V_ex being the velocity amplitude which is equal to 0.30U_c, and f_ex the perturbation frequency. The injection is made at an angle of 45 degrees relative to the streamwise direction.

The grid data are available in text format. There are two sets of grid, a coarse one comprising 118x100 grids and a doubles grid with 236x200 grids. Files are available as below:

- grid_S.txt: 118x100 grids, 4.5kB
- grid_L.txt: 236x200 grids, 9.3kB
- README_Stp.txt: Some instruction on the grid arrangement.

Related Papers

1. Yoshioka, S., Obi, S. and Masuda, S. (2000), "Effect of periodic perturbation on the vortex structure of the turbulent separated flow over the backward-facing step," Proc. 3rd International Symposium on Turbulence, Heat and Mass Transfer, pp. 605-612.
2. Yoshioka, S., Obi, S. and Masuda, S. (1998),hRole of the vertex motion in the periodically perturbed turbulent flow over the backward-facing step,h Proc. of 4th KSME Fluids Eng. Conf. pp.585-588.
3. Rhee, G. H. and Sung, H. J. (2000) "Numerical prediction of locally forced turbulent separated and reattaching flow," Fluid Dynamics Research, Vol. 26, pp. 421-436.
4. Chun, K. B. and Sung, H. J. (1996),hControl of turbulent separated flow over a backward-facing step by local forcing,h Experiments in Fluids,Vol.21,pp.417-426.

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