Inlet fluctuating boundary conditions for 3D Hill Flow

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1 Description

Synthetic inlet fluctuations are created using the method described in [1, 2]. The provided Matlab code does Item 1 and 2 below. The code includes the following steps.

1. Isotropic, homogeneous turbulence is first created on a mesh ($N_j = 80$, $N_k = 128$ cells) at the inlet plane which has 8% stretching from the two walls. This is denoted the η grid. This means that the fluctuations in the first 11 cells on the CFD grid (denoted the y grid, see Item 3 below) vary linearly between 0 and the value at the first η cell. In the spanwise direction the grid spacing of the CFD grid is used. The kinematic viscosity is 1/130 000.

   - 600 modes are used $N = 600$ (see Eq. 3 in [1]). The number of modes is high because $\min(\Delta\eta)$ is small which means that the CPU time for generating the fluctuations for the 5000 files is not negligible large (half an hour on a single core of a standard PC). Since we generate the fluctuations once and store them on disk, the required CPU time is of no concern. However, if this procedure were to be used at run time, we could maybe let $\Delta\eta \equiv \Delta z$ so that $N = 32$; this reduces the required CPU time by one order of magnitude.
   - $\kappa_{max} = 2\pi/\min(\Delta\eta)$ (see Item 2 at p. 7 in [1])
   - $p = 4$, $L_t = 0.1\delta = 0.05\ m$ (see Item 3 at p. 7 in [1])
   - $u_{rms} = u_{\tau,inlet} = 1/25\ m/s$ (see Eq. 4 in [1])
   - $\varepsilon = u_{rms}^3/L_t$ (see Eq. 4 in [1])

2. 5000 files are created with u', v' and w' (see Eq. 3 in [1])

3. The data in these 5000 files are interpolated from the η grid to the hump mesh (the y grid). The velocities are set to zero at the walls which means that the turbulence is homogeneous in the entire plane except over the distance $\Delta\eta$ near both walls over which the velocities decay linearly to zero.

4. At run time the files are read (see file `set_inlet_bc.f`).

5. At run time a time correlation is introduced (see Eq. 5 in [1]) with $\mathcal{T} = 0.05\delta/u_\tau$ (see file `set_inlet_bc.f`). Outside the boundary layers, the fluctuations are dampened by use of a blending function (see Eq. 4 in [2] and `set_inlet_bc.f`). The blending function reads

$$f_{bl} = \min\left\{0.5\left[1 - \tanh(n - \delta)/b\right], 0.1\right\}$$

where n is the distance to the nearest wall and $b = 0.1m$ is the distance over which f_{bl} goes from 1 to 0. $\delta = 0.5m$. Freestream turbulence is prescribed by not letting f_{bl} become smaller than 0.1. A code for generating synthetic fluctuations (Item 1 and 2) are given in form of Matlab routines, see next section.

2 Matlab files

The Matlab files `angles.m`, `randf_1.m`, `randf_2.m` and `synt_main.m` can be downloaded.

2.1 `synt_main.m`

In Chapter 1 length scale, constants and the grid are defined. The inlet plane is assumed to be located at $x =$ const, i.e. the inlet plane is a $y - z$ $(j - k)$ plane. The CFD grid in the z direction is read and for simplicity only one cell is used in the y direction ($nj = 2$).
Random numbers are used. A random generator needs a seed; the sum of the current hour, minute and second (the three last elements generated by the Matlab command `clock`) is used as a seed. This means that a different random velocity field will be generated every time you run the code.

In Chapter 2 the loop over `ntstep` realizations ("time steps") starts.

In Chapter 3 the loop over the inlet grid plane starts.

2.2 `angles.m`

In this file the angles φ^n, ψ^n, α^n and θ^n are computed for each wavenumber n by calling the function `rand1`.

2.3 `rand1.m`

In this file the upper and lower limits of the random numbers are set.

2.4 `rand2.m`

In this file random numbers are generated. The function corresponds to `ran1` in *Numerical Recipes in C: The Art of Scientific Computing*, Second Edition.

References

[1] L. Davidson. Using isotropic synthetic fluctuations as inlet boundary conditions for unsteady simulations. *Advances and Applications in Fluid Mechanics*, 1(1):1–35, 2007.

[2] L. Davidson. Hybrid LES-RANS: Inlet boundary conditions for flows including recirculation. In *5th International Symposium on Turbulence and Shear Flow Phenomena*, volume 2, pages 689–694, 27-29 August, Munich, Germany, 2007.