Fully-developed, pressure-driven flow of an incompressible, isothermal fluid through a plane open channel flow : data from DNS

Reference: Direct numerical simulation of turbulent open channel flow: Streamwise turbulence intensity scaling and its relation to large-scale coherent motions, *proceedings of the 10th iTi conference on turbulence*, 2023.

Note that a publication is in process. When using the data please check

www.ifh.kit.edu/dns_data/channel/smooth/open/

again for the final reference.

Description of the flow

We are considering the flow of an incompressible and isothermal fluid in a plane open channel flow of height h (cf. figure 1). The flow field is assumed to be periodic in stream- and spanwise direction over periods of length L_x and L_z, respectively. A constant flow rate is imposed at each time step.

Flow parameters

The problem is governed by a single parameter, the bulk Reynolds number $Re_b = u_b h/\nu$, where u_b is the bulk velocity and ν the kinematic viscosity. Table 1 shows the simulated Reynolds number values.

Numerical method

The data was obtained from direct numerical simulations of open channel flow using a pseudo-spectral method which solves the wall-normal velocity/vorticity formulation of the Navier-Stokes equation introduced by Kim et al. [1].

- Euler implicit scheme for the viscous terms;
- three-step low-storage Runge-Kutta method for the non-linear terms;
- truncated Fourier series in streamwise and spanwise directions (2/3 de-aliasing), Chebyshev polynomials in the wall-normal direction on a Chebyshev-Gauss-Lobatto (CGL) grid;
- no-slip boundary at the bottom wall and the free-slip boundary condition at the top wall, impermeability boundary condition at bottom and top wall, periodic boundary conditions in z direction;

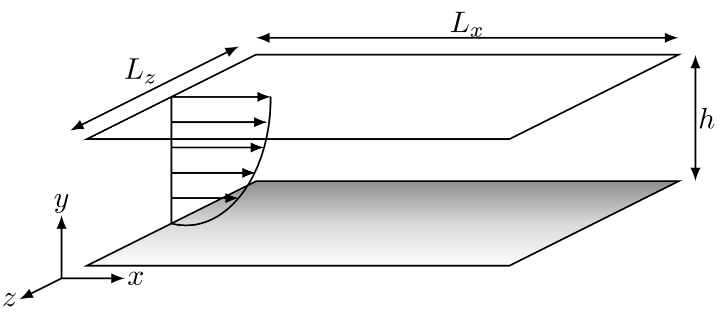

Figure 1: The geometry of the problem and the computational domain.

Numerical parameters

The data included in this repository is characterized by the following features:

- friction Reynolds numbers: $200 \leq \mathrm{Re}_\tau \leq 895$.
- streamwise domain length: $4\pi h \leq L_x \leq 12\pi h$.
- spanwise domain length: $2\pi h \leq L_z \leq 12\pi h$.
- time step: CFL ≤ 0.5;
- streamwise grid spacing: $\Delta x^+ \leq 15$;
- spanwise grid spacing: $\Delta x^+ \leq 5.5$;
- maximum wall-normal grid-spacing: $max(\Delta y^+) \leq 3.7$;

case	Re_τ	Re_b	L_x/h	L_z/h	N_x	N_y	N_z	Δx^+	Δz^+	Δy^+_{min}	Δy^+_{max}
O200	200.38	3170	12π	4π	768	129	512	9.8	4.9	0.03	2.46
O200W12	200.43	3170	12π	12π	768	129	1536	9.8	4.9	0.03	2.46
O400	398.73	6969	12π	4π	1536	193	1024	9.8	4.9	0.03	3.26
O600	596.26	11047	12π	4π	1536	257	1536	14.6	4.9	0.02	3.66
O600W8	602.26	11047	12π	8π	2048	257	2048	11.1	7.4	0.02	3.70
O900L4	989.84	17512	4π	2π	1536	385	1024	7.4	5.5	0.02	3.68
O900L8	895.34	17512	8π	4π	2048	385	2048	11.0	5.5	0.02	3.66
O900	895.18	17512	12π	4π	3072	385	2048	11.0	5.5	0.02	3.66

case	ν	u_τ	u_b	$t_{stat}u_b/h$
O200	4.20575e-04	0.0421381	0.666667	8660
O200W12	4.20575e-04	0.0421475	0.666667	3254
O400	1.91322e-04	0.0381428	0.666667	1925
O600	1.20700e-04	0.0359843	0.666667	1460
O600W8	1.20700e-04	0.0363462	0.666667	
O900L4	7.61385e-05	0.0342183	0.666667	417
O900L8	7.61385e-05	0.0340850	0.666667	570
O900	7.61385e-05	0.0340788	0.666667	1054

Table 1: Simulation parameters: bulk Reynolds number Re_b, friction-velocity Reynolds number Re_τ, number of streamwise and spanwise Fourier mode N_x and N_z, number of wall-normal Chebyshev polynomials N_y, streamwise and spanwise grid spacing in wall units Δx^+ and Δz^+, minimum and maximum wall-normal grid spacing in wall units Δy^+_{min} and Δy^+_{max}, respectively, kinematic viscosity ν, friction velocity u_τ, bulk velocity u_b, statistics interval t_{stat} in bulk units.

Available data

The folders are structured as follows. Each case folder contains statistical data in ASCII file format similar to the ones provided by https://turbulence.oden.utexas.edu/. Statistical quantities are obtained by averaging in time as well as in streamwise and spanwise direction. They are usually normalised in wall units, otherwise mentioned in the data file header.

profiles: wall-normal profiles of one-point statistics

case.means	mean velocity profile
case.reystress	Reynolds stress profiles
case.vort	root-mean-square vorticity profiles
case.tautot	shear stress profiles
case.velp	velocity-pressure correlation profiles
case.highorder	velocity skewness and flatness profiles

balances: wall-normal profiles of one-point statistics

case.tke	turbulent kinetic energy budget
case.uubal	$\langle u'u' \rangle$ budget
case.vvbal	$\langle v'v' \rangle$ budget
case.wwbal	$\langle w'w' \rangle$ budget
case.uvbal	$\langle u'v' \rangle$ budget

corr: 1D two-point correlations at different wall distances

case.xcorr.*yplus*	streamwise velocity correlations at $y^+ = yplus$
case.zcorr.*yplus*	spanwise velocity correlations at $y^+ = yplus$

spectra: 1D velocity spectra at different wall distances

case.xspec.*yplus*	streamwise velocity spectra at $y^+ = yplus$
case.zspec.*yplus*	spanwise velocity spectra at $y^+ = yplus$

corr2d: 2D two-point correlations at different wall distances

ruu_re$X$_yp$Y$_Zp.dat	positive streamwise velocity correlation iso-contours at Re $= X$, $y^+ = Y$ in Z=b(ulk)/w(all) units
ruu_re$X$_yp$Y$_Zp.dat	negative streamwise velocity correlation iso-contours at Re $= X$, $y^+ = Y$ in Z=b(ulk)/w(all) units

Data format and location

Data is presented in the form of ASCII files. Further information is given in the header of the corresponding file The data is located below the following URL:

doi.org/10.4121/88678f02-2a34-4452-8534-6361fc34d06b
www.ifh.kit.edu/dns_data/channel/smooth/open/

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References

[1] John Kim, Parviz Moin, and Robert Moser. Turbulence statistics in fully developed channel flow at low Reynolds number. *Journal of Fluid Mechanics*, 177:133–166, 1987. doi:10.1017/S0022112087000892.