LARGE-EDDY SIMULATION FOR COMBINED OSCILLATORY THROUGH-FLOW AND STEADY CURRENT OVER ROUGHNESS ELEMENTS

Zhengtong XIE, Ian P. CASTRO
School of Engineering Sciences, University of Southampton, Southampton SO17 1BJ, UK,
email: z.xie@soton.ac.uk, i.castro@soton.ac.uk

Understanding the mechanism by which the urban boundary layer and the regional weather model are coupled aerodynamically and thermodynamically is known to be vital but is still in its infancy. Unsteadiness of the large scale driving wind probably has significant impact on the turbulent flows within the urban boundary layer [4]. Oscillatory flow and combined oscillatory throughflow and mean current have attracted researchers' attention for decades, with most studies being experimental work [1,2,3,4]. In their study of channel flow with a roughened (rippled) wall, Chang & Scotti [2] found that the effect of an oscillation in the imposed pressure gradient was to increase the drag noticeably. Sleath [4] investigated the turbulence statistics and coherent structures of an oscillatory flow over rough wall (sand, gravel or pebbles). He found that the coherent structures change the manner of momentum transfer significantly. So a time-varying external driving force can certainly make a difference to the turbulent flow.

Flow over groups of cubes mounted on a wall provides an excellent test case for validation. Understanding of such flows is also directly beneficial to the understanding of the roughness sublayer, urban meteorology, etc. As a start, for investigating unsteady large-scale driving flows, we numerically simulated a combined oscillatory throughflow and current (here labelled as "C20SOI") over a group of cube arrays (eight rows of cubes) using an efficient inflow-generating method which we developed recently. An assumption was made here that at the inlet the turbulent fluctuations, e.g. $u_{rms}, v_{rms}, w_{rms}$ are in phase with the mean streamwise velocity, $U = U_0[1.0 + 0.5\sin(2\pi t/T)]$, where U is the phase averaged streamwise velocity, U_0 is the mean streamwise velocity of the current, $T = 322.6h/u_*$ is the oscillation period, h is the height of cube and u_* is the mean friction velocity.

For the same computational domain LES, applying a combined oscillatory and steady pressure gradient with a streamwise periodic boundary condition, was also conducted (labelled here as "C20SOP"). We noted that a smaller domain (i.e. two rows of cubes) is not desirable for such computation. The unsteady pressure gradient for C20SOP is written as follows, $\frac{dP}{dx} = -\frac{\rho}{D}\{u_*[1.0 + 0.5\sin(2\pi t/T)]\}^2$, where $D = 4h$ is the depth of the domain and ρ is the density. The mean streamwise velocity is assumed approximately as, $U = U_0[1 + \alpha \sin(2\pi t/T - \phi)]$, where α is a parameter to be obtained by using fitting method and ϕ is the lag phase. The velocity $r.m.s$ values $(u_{rms}, v_{rms}, w_{rms})$ are assumed to be of similar form as the above equation.

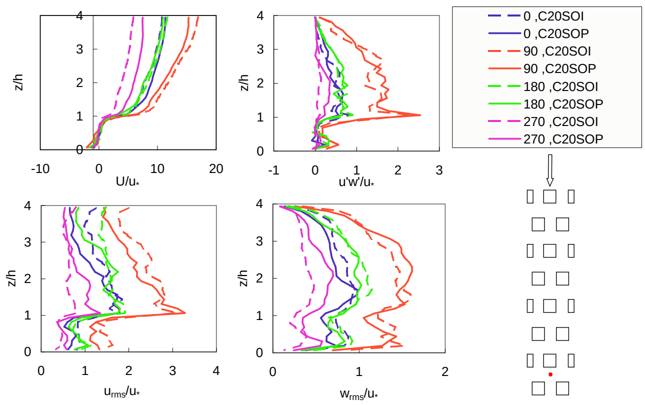

Figure 1: Vertical profiles of phase averaged turbulence statistics

We found that the phase lags of U, $\overline{u'w'}$, u_{rms}, w_{rms} are approximately 45 degree at all heights for C20SOP. Figure 1 shows a comparison of phase averaged turbulence statistics between C20SOI and C20SOP. Note that here for C20SOP the phase is $2\pi t/T - \phi$ and that the phase-averaged statistics were obtained behind row seven.

A comparison of the results obtained from the two methods is one focus of the presentation. An investigation of the mechanism of the combined oscillatory throughflow and mean current is also attempted.

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