INVESTIGATION OF IMPACT OF SECONDARY FLOWS IN TURBULENT OPEN-CHANNEL FLOWS USING DNS DATA

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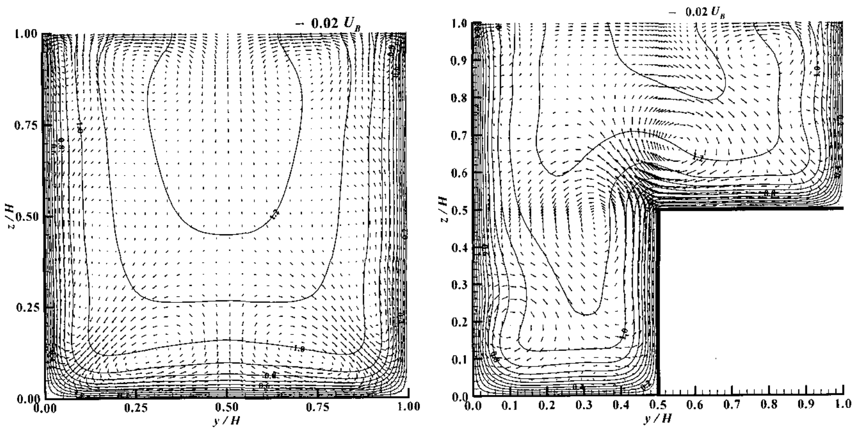
Accurate estimation of the wall shear stress in turbulent open-channel flows is important in engineering practices. Because the wall shear stress or shear velocity is a key parameter determining mean streamwise velocity, bed erosion and deposition, bank erosion, transport of solute contaminant, and etc. Meanwhile, the secondary flows generated by turbulence anisotropy in turbulent open-channel flows are known to affect the mean flow and turbulence structures. Since, in the region where the secondary flows affect significantly the flow, the velocity distribution can significantly be different from that from the standard log-law, the use of the law of the wall used frequently for wall bounded flows in turbulence modelings may not be appropriate.

This study presents DNS of turbulent flows in both rectangular and compound open-channels. The simulated mean flow data are compared with numerical and experimental data available in the literature.

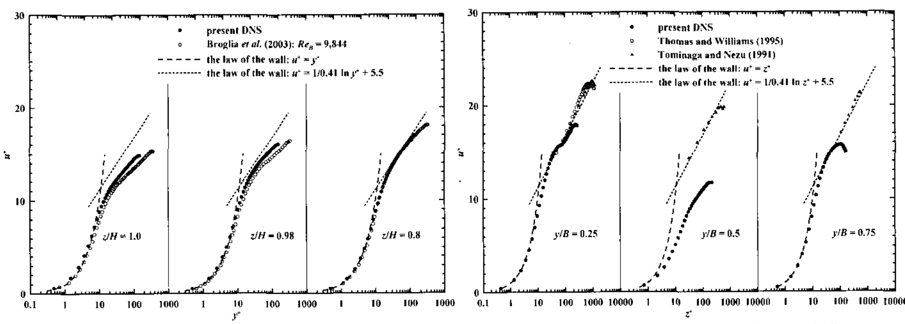
For the rectangular open-channel flows in Fig. 1(a), DNS reproduce a velocity-dip phenomenon and both inner and outer secondary flows. Particularly, it is found that the inner secondary flows significantly affect the wall shear stress near the free surface although their size and magnitude are smaller than those of the outer secondary flows. For the compound open-channel flows in Fig. 1(b), the twin vortices are generated near the juncture of the main channel and the floodplain. The maximum magnitude of secondary flows is about 5% of bulk streamwise velocity, which is greater than the one in square duct flows or in rectangular open-channel flows. Near the juncture, the contour lines of mean streamwise velocity are found to be bulged significantly towards the flow direction of the twin vortices.

It is also found that the mean streamwise velocity does not satisfy the log-law in the region where strong secondary flows are observed (see Fig. 2). This happens for both rectangular and compound open-channel flows. Moreover, from the present DNS data and LES data in the literature, the wall shear stress shows a peak value at the free surface and at the juncture for the rectangular and compound open-channel flows, respectively (see Fig. 3). However, the same trend is not observed in the measured data. This is resulted from improper estimation of the shear velocity in the experiments.



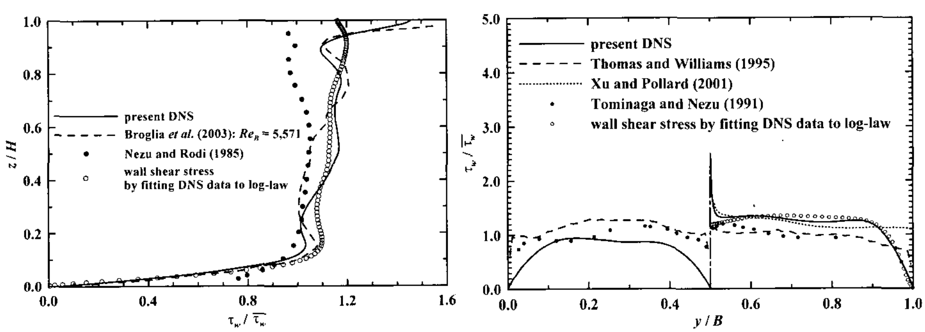
(a) rectangular open-channel flows (b) compound open-channel flows

Fig. 1 Mean velocity fields.



(a) rectangular open-channel flows (b) compound open-channel flows

Fig. 2 Mean streamwise velocity profiles in wall units for three different regions.



(a) rectangular open-channel flows (b) compound open-channel flows

Fig. 3 Wall shear stresses.