On the effect of the distance between longitudinally ridged walls in a turbulent channel flow

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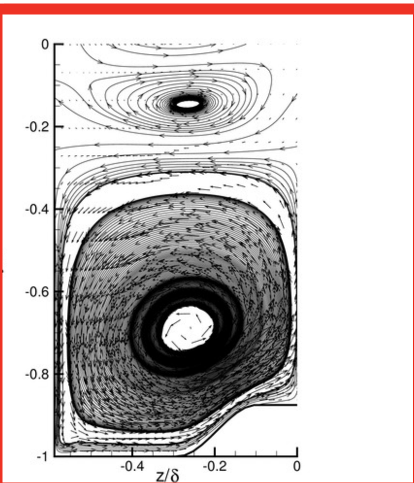

Figure 1: streamlines in Case A

Direct numerical simulation (DNS) of a turbulent channel flow with longitudinally ridged walls set at different distances has been carried out and results are analysed and presented. Cases A and B are similar to cases I and J of Nezu and Nagawaga (1984) [3], where a distance between the ridged walls of 0.25 δ and 0.5 δ, respectively, has been used. The third case C is based on a four-folded (δ) distance to realise the domain width effect.

Domain dependence study shows that additional large circulation bubbles appear even at a very low Reynolds (Re_τ= 150). Somehow this has not been captured in previous DNS of Kawamura and Sumori (1999) [2] (KS hereafter) and LES of Falcomer and Armenio (2002) [1]. Furthermore, it was found that as the distance between the ridged walls increases, the recirculation bubbles appear much close to the bottom side of the channel.

In order to improve discontinuity in numerical derivatives, the mesh used is slightly rounded off at the corner of the ridged walls, and also a fine-tuning stretching factor is applied in the spanwise direction to allow near-orthogonal angles between the normal and the spanwise coordinates.

Figure 1 depicts Case A results using the same configuration of KS. The main large recirculation, previously shown by KS, is clearly captured by present study even on a coarse mesh resolution ($\triangle x^+$ 11.85, $\triangle y^+$: 2.1-10.4, $\triangle z^+$ 3.2-7.6), while using a refined mesh in the spanwise direction ($\triangle z^+$: 2:1-4:9) a tertiary flow appears near the center of the channel. This recirculation is very difficult to capture due to its extremely small intensity in terms of the spanwise and the normale velocity components (only 0.1% of the streamwise current) and also low frequency level so that minimum time units of 1600= δ/u_τ are required to have fully converged statistics.

Figure 2 shows a vector plot and streamlines from Case B (doubling distance in the spanwise direction). It can be seen that the tertiary recirculation bubbles previously presented near the center of the channel disappears, and instead there are two small additional recirculation bubbles appear on the bottom side of the ridged walls. Again, their intensities are very small (only about 0.15% of the main

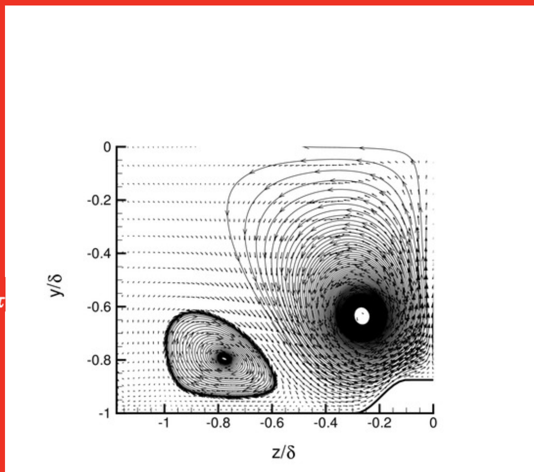

Figure 2: streamlines in Case B

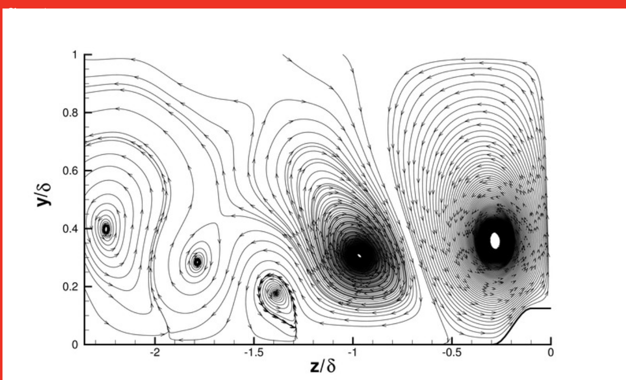

Figure 3: streamlines in Case C

Finally, Figure 3 shows the streamlines for case C) (fourfolded distance): tertiary and quaternary recirculations are captured. Their intensity are 20% and 12% of the secondary recirculation.

Those results suggest that a cascade effect could be initialised in a multiphase system (like water and sand) which will eventually form a regular distribution of longitudinally ridgeds (like sand ribbons in a river).

[1] L. Falcomer and V. Armenio. Large-eddy simulation of secondary flow over longitudinally ridged walls. Journal of Turbulence, 3(8):1, 2002.

[2] H. Kawamura and T. Sumori. Dns of turbulent flow in a channel with longitudinally ridge walls. ERCOFTAC SERIES, 7:405, 1999.

[3] I. Nezu and H. Nakagawa. Cellular secondary currents in straight conduit. Journal of Hydraulic Engineering, 110(2):173, 1984.