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Direct Numerical Simulations (DNS) of Turbulent Flow in a Wavy Channel

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Abstract

In the past few years, DNS of viscoelastic turbulent channel flow have been performed to investigate the mechanism of polymer-induced drag reduction. However, the flow problems become much more complicated in the presence of irregular geometries due to the inherent complexity of the governing equations which are very computationally intensive by using currently available numerical techniques, even when the fluid is assumed to be Newtonian. In this work, we have successfully developed an accurate (spectral accuracy) and efficient (almost linear workload) Helmholtz solver, based on a spectrally preconditioned Bi-CGSTAB algorithm, for DNS of turbulent flow in undulating channel geometries. We performed DNS of Newtonian turbulent flow in a channel geometry involving a single sinusoidal solid wavy wall with amplitude/half width ratio of 0.1 and a wave length of 2. Two different friction Reynolds numbers have been investigated, $\mathrm{Re}_\tau = 160$ and 220 corresponding to mean Reynolds numbers (based on the channel half width) 1800 and 2480, respectively. The computational domain used was $10 \times 2 \times 5$ along the streamwise, shearwise and spanwise direction respectively, with spectral resolutions ranging from $160 \times 257 \times 64$ to $320 \times 385 \times 128$. The numerical results compare well against Hudson's measurements (Hudson, 1993). In addition, the DNS results allowed us to investigate in detail various turbulence statistics and the vorticity structure and its influence from the wall undulation.