EXPERIMENTAL STUDY OF OSCILLATING-GRID TURBULENCE INTERACTING WITH A PERMEABLE BOUNDARY

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Recent work (by the present authors) [1] provided new insight into the study of the interaction of zero-mean-shear turbulence with a solid boundary by experimental measurements using oscillating-grid turbulence (OGT). In previous work (focusing largely on otherwise homogeneous turbulence) conflicting theories have been proposed to describe the affect, in zero-mean-shear turbulence, of a boundary on inter-component energy transfer, which was thought to be significant in determining the magnitude of second-order turbulent statistics in the boundary-affected region [2, 3]. In contrast, it has now been proposed that in turbulence that is inhomogeneous in the boundary-normal direction, the resulting turbulent kinetic energy flux towards the boundary is significant in determining the affect of the boundary [1]. Specifically, the blocking of the energy flux (due to the impermeability condition) directly leads to an increase in the magnitude of rms boundary-tangential velocity components (relative to their values in the absence of a boundary). As a result, this leads to an increase in inter-component energy transfer in the boundary-affected region [1], away from a thin region close to the boundary in which viscous effects are dominant [2]. Here we present new results studying the interaction of OGT with permeable boundaries, thereby weakening the blocking condition imposed by the solid boundary and inhibiting the affects of the blocking of the energy flux at the boundary.

2D planar PIV was used to analyse the interaction of turbulence with a horizontal permeable boundary (reticulated polyether foam), in a central vertical plane of a cuboidal tank. Experiments were performed using water in the tank stirred by a vertically oscillating grid. Under ideal conditions, the oscillating grid turbulence (OGT) produced is statistically stationary, homogeneous and isotropic in planes parallel to the grid, with negligible mean flow [4], providing a good approximation to zero-mean shear conditions. Reynolds number conditions were varied by changing the stroke, S, and frequency of oscillation, f, with a fixed grid mesh spacing, M, to consider the Reynolds number range $R_e \equiv MSf/\nu \approx 2000 - 8000$. Using a boundary of absolute permeability, K, approximately equal to $1.1 \times 10^{-8}\,\mathrm{m}^2$, results comparable to that of an impermeable boundary [1] are obtained across the Reynolds number range considered. However, when using a more permeable boundary, $K \approx 1.7 \times 10^{-7}\,\mathrm{m}^2$, notable differences are observed, indicating a reduction in the blocking effect. In contrast to results of previous work considering the interaction of OGT at boundaries [1, 5, 6, 7], when studying the interaction at the permeable boundary clear Reynolds number effects are observed. Terms in the transport equations for the Reynolds stress tensor [8] are used to explore the underlying mechanisms of this process. The relaxation in the blocking condition inhibits the formation of the previously identified distinct peaks in the turbulent transport terms, indicative of the blocking of the turbulent kinetic flux [1].

References

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