PIV and μ-PTV investigations of turbulent flow over a flexible wall undergoing traveling surface wave motions

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HIGHLIGHTS

- Drag reduction effects by spanwise traveling surface waves with wall deformation in a fully turbulent flat plate boundary layer are investigated experimentally by PIV and μ-PTV.
- A parametric study is performed downstream and above the moving surface regarding the wave parameters frequency and amplitude.
- Within the range of the parameters investigated, the drag reduction ratio increases with increasing amplitude and frequency.
- The turbulence statistics in the near-wall region show that the RMS values of the streamwise and the wall-normal velocity are suppressed. The Q2 and Q4 events are weakened by the spanwise traveling surface wave motions.

ABSTRACT

Drag reduction effects by spanwise traveling surface waves with wall deformation are investigated experimentally using particle-image velocimetry (PIV) and micro-particle tracking velocimetry (μ-PTV) in a fully developed zero pressure gradient turbulent boundary layer. Since the wave parameters, i.e., wave amplitude ($A$), and frequency ($T$) are relevant factors for the drag reduction effect, a parametric study is performed to analyze their influence on the drag reduction. Within the range of the parameters investigated, the maximum drag reduction of 3.8% is found at $A = 11.8$ and $T = 158$ (figure 1). Furthermore, the turbulent boundary layer flow above the wave crest and trough is investigated by the phase-locked measurements. The results showed that the drag reduction effect is not only enhanced by increasing the amplitude, but also by raising the frequency in the range of the current parameters. Regarding the turbulence statistics downstream and above the moving surface, the velocity fluctuations in the streamwise and the wall-normal directions are damped by the traveling surface wave motion. A quadrant analysis of the turbulent production shows that the sweep and ejection events are also weakened.

Fig. 1 Drag reduction ratio derived from the μ-PTV measurements as a function of frequency and amplitude. The values for $f = 81$ Hz ($T = 110$) are taken from Roggenkamp et al. [1].