Experimental investigation on the effects of surfactant on a turbulent boundary layer flow

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Drag reduction effect in turbulent ow by small concentrations of surfactants is a well known experimental observation. The changes could be spectacular with only few parts per million (ppm) of the surfactant solution added to the solvent. The drag reduction effect is accompanied by the modi cation of the turbulence structure by surfactant. One of the surfactant effects that was reported by almost all researches is the increased anisotropy when the wall-normal velocity uctuations are considerably suppressed. Such observation have lead to the conclusion that the main reason of the decrease in the Reynolds stresses values is the decorrelation of the streamwise and wall-normal components of the velocity uctuations. The drag reducing effect of a dilute solution of bio-degradable (Agnique PG 264-U) surfactant from the Alkyl Polyglycosides was investigated experimentally. In the present study, particle image velocimetry (PIV) was applied to the investigation of a ow in the streamwise-spanwise plane of a turbulent boundary layer in a ume at $y^+ = 80$ (Fig. 1).

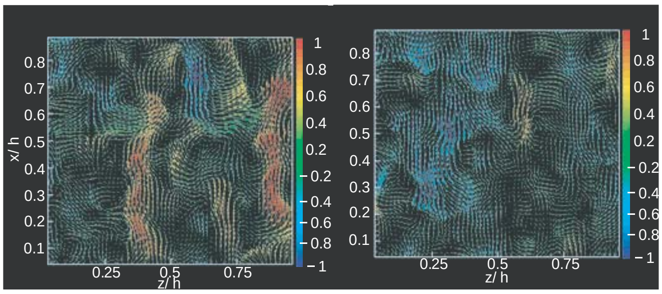

Fig. 1 The uctuating velocity eld in the streamwise–spanwise plane of the water ow (left) and the ow with surfactant (right). The color scale represents the values of the streamwise velocity uctuations in cm·s^{-1} (i.e., $-1 \le u^{?} \le 1$ cm·s^{-1}).

The results present a comparison between the water and surfactant solution ows at the same ow rate, as characterized by the Reynolds stress, turbulent energy production and the spatial distribution of the mean shear. The in uence of the surfactant solution on the turbulent ow and its structure is clearly seen in different distributions of one-point correlation elds of $?u^{?}w^{?}?$ and turbulent kinetic energy production $?u^{?}w^{?}?S_{uw}$. The bio-degradable surfactant was shown to be an ef cient drag reducing solution, acting in parallel on the elds of Reynolds stress component, and mean shear $\partial U/\partial z$ (e.g., Gurka et al. 2004). The presented results support the explanation of the mechanisms responsible for the drag reduction, reviewed for example by Tsinober (2001). The analysis of distribution of the uctuating velocity suggests that the uctuations in the drag reducing ow are only slightly decreased. The Reynolds stress component $?u^{?}w^{?}?$ is suppressed more signi cantly than the r.m.s of the streamwise velocity uctuations, $?u^{?2}?^{1/2}$, what implies the decorrelation effect.

Furthermore, the turbulent kinetic energy production term in the streamwise-spanwise plane diminishes in the ow with surfactant, similarly to the known effect in the streamwise-wall normal plane. Proper orthogonal decomposition (POD) shows (Fig. 2) that the coherent structure of the ow does not disappear when the surfactant is introduced, but changes its spatial characteristics, i.e. from elongated regions of alternating positive/negative strips (Liberzon et al., 2005) to the less regular spots of wall-normal component of vorticity, ω_y.

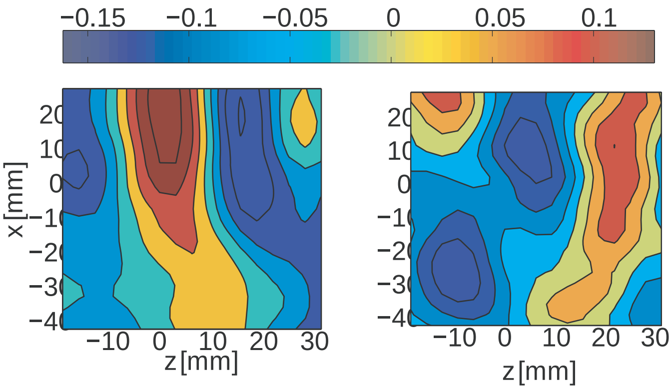

Fig. 2 Liner combination of the rst three POD modes of the wall-normal vorticity component, ω_y, measured in the streamwise-spanwise plane for the water (left) and the surfactant solution ow (right).

References

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