Extraction of secondary instability of streaks in turbulent boundary layer using linear response

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In this study, the method of extracting coherent structures with linear response developed by Matsubara.et.al[1] is applied to a turbulent boundary layer to investigate the secondary instability of the streaks near the wall. Artificial disturbances are introduced into the turbulent boundary layer on a flat plate in a wind tunnel, and the coherent structure of the flow is extracted by ensemble (periodic) averaging of velocity fluctuations downstream of the disturbance measured by a hot-wire anemometer. The artificial disturbance was a sine-shaped velocity fluctuation with two frequencies of 50 Hz for the streak and 500 Hz for the secondary instability of the streak, respectively. Figure 1 shows isosurfaces of the periodic components of the measured velocity fluctuations. $X^+ = -\phi U_c^+$ is the streamwise position in wall units estimated by Taylor's frozen flow hypothesis with the advection velocity of the streak $U_c^+ = 13.5$ obtained by Matsubara et al.[2] and a phase time ϕ. In both periodic fluctuation components $\widetilde{u}_L$ with only low-frequency disturbances and $\widetilde{u}_H$ with only high-frequency disturbances, the low-speed and high-speed regions appear alternately. With the disturbances with both high and low frequencies, $\widetilde{u}_{LH}$ marked in (c), the high-frequency disturbance is noticeable in the low-speed region. (d) shows $\Delta u = \widetilde{u}_{LH} - \widetilde{u}_L - \widetilde{u}_H$, which is the increase or decrease of the secondary instability when they are inserted simultaneously. On the low-speed streak, high-frequency turbulence is amplified, and the structure rides up on the downstream structure. On the other hand, high-frequency disturbances are attenuated on the high-speed streak. The fact that this enhancement of the secondary instability without appearing inflectional profiles in $\widetilde{u}_L$ indicates that secondary instability in the inflectional distributions, which was originally distorted by streaks in the turbulent boundary layer, being enhanced by artificial disturbance and extracted.

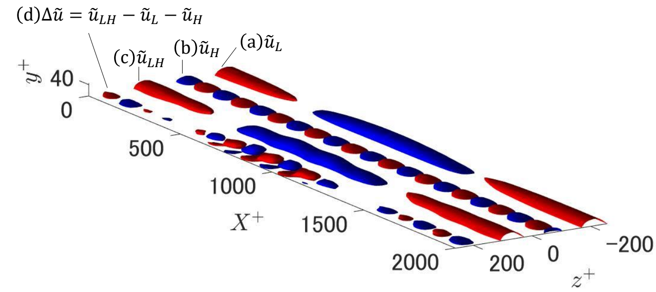

Figure 1: Isosurface diagrams of periodic fluctuation components.

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[1]Matsubara, M, Alfredsson, P. H., Segalini, A, *J. Fluid Mech.* **888**, (2009), A26.

[2]Matsubara, M, Nagasaki, M, Yokoi, M, Azmeer, M, *Proceedings of ICJWSF2015.* Springer Proceedings in Physics, **185**, (2016), pp. 311-316.