Spatially and temporally resolved 2C-2D PIV in the inner layer of a high Reynolds number adverse pressure gradient turbulent boundary layer

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HIGHLIGHTS

• An adverse gradient turbulent boundary layer (APG-TBL) flow was measured: (1) using high framing rate high-spatial resolution 2C-2D PIV in a streamwise - wall-normal plane and (2) using high spatial resolution 2C-2D PIV in streamwise – spanwise planes.
• The first of these measurements provides time series of the streamwise and wall-normal velocity components in the APG-TBL up to $y^+ = 426$ and wall-shear stress, as well as unprecedentedly resolved velocity and wall-shear stress statistics.
• The streamwise – spanwise plane 2C-2D PIV provides information on the spanwise scale of low and high momentum regions in the upper viscous and lower and upper buffer region of the APG-TBL.

ABSTRACT

A joint experiment was performed in May 2015 in the framework of the European Project EuHIT: "European High performance Infrastructures in Turbulence". One of the aims was a detailed study of a high Reynolds number turbulent boundary layer flow under adverse pressure gradient (APG-TBL) to determine the effect of the pressure gradient on the spatio-temporal character of structures in the inner layer. Highly spatially resolved time series of up to 250,000 samples in length of the streamwise and wall-normal velocity component were measured using 2C-2D PIV with single-exposed image pairs acquired at frequencies up to 6.7 kHz. The domain of these measurements spanned 5 x 25 mm$^2$ corresponding to a domain of up to $85^+ x 426^+$ with the spatial resolution of the velocity measurements ranging from 0.4$^+$ to 0.7$. Using these highly spatially and temporally resolved velocity measurements, time series of the wall-shear stress, spectra of the velocities, statistics and other pertinent characteristics of the APG-TBL were extracted and analysed. 2C-2D PIV using a sCMOS camera with 2560 x 2160 px resolution and 16 bit dynamic range was undertaken in streamwise-spanwise planes spanning 14.6 x 17.3 mm$^2$, which corresponds to a domain of up to $250^+ x 300^+$. The spatial resolution of these velocity measurements is 0.9$. The camera was equipped with a Zeiss lens of 100 mm focal length with a teleconverter. f2.0 was used for these experiments, resulting in an estimated depth-of-field of 170 $\mu$m and a diffraction limited diameter of approximately 10 $\mu$m. These measurements provide pertinent spanwise characteristics of the low and high momentum zones at different wall-normal distances in the APG-TBL.