SINGLE PIXEL PIV STUDY OF ADVERSE-PRESSURE-GRADIENT TURBULENT BOUNDARY LAYERS

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The quest for a better understanding of wall-bounded turbulent flows has been one of the main goals of the turbulence research. These flows are one of the most widely studied problems given their ubiquitous presence in many relevant fluid-flow applications such as the flow over wings, land and sea vehicles, turbines, compressors, etc. Due to the complex physics present in these flows, simplified scenarios such as the zero pressure gradient (ZPG) turbulent boundary layer (TBL) developing over a flat plate have been investigated over the years in order to understand the fundamental aspects of wall-bounded turbulence. Unfortunately, most flows of relevance in technical applications are exposed to adverse pressure gradients (APG) in which the applicability of the knowledge from ZPG TBL flows is restricted. Although a number of simulations and experiments on (APG TBLs) have been performed in the past, it is hard to draw firm conclusions from the available data due to the differently varying streamwise evolution of the Clauser pressure-gradient parameter β, *i.e.*, in the various studies the TBL was exposed to different flow histories leading to a particular pressure gradient condition. Most of these studies were focused only on statistical properties, which means that little is known about the topological features of the coherent structures and their dynamics in these flows. A detailed understanding of these structures may lead to an improvement in turbulence theory, modelling and flow control strategies, since it is well known that large-scale motions play a crucial role in the fundamental mechanisms of wall-bounded turbulence. Particularly for APG flows there is an increase in large-scale, outer-region activity as the pressure gradient is increased which leads to a stronger interaction with the near-wall region when compared with the ZPG case. Therefore, even the region close to the wall is crucially affected by the pressure gradient.

The present contribution aims therefore at studying the structure of different APG TBLs through simulations [2] and experiments, in order to study the effect of the imposed pressure gradient. To this end, an extensive experimental campaign was carried out at the Minimum Turbulence Level (MTL) wind tunnel at KTH Royal Institute of Technology. Hot-wire anemometry and Particle Image Velocimetry (PIV) measurements were performed in the Reynolds-number range 450 < Re_θ< 25,000 (where Re_θ is the Reynolds number based on momentum thickness), and in the range of pressure-gradient conditions 0 < β < 3.1. The desired pressure-gradient conditions and flow histories were established by means of wall inserts, and the wall-shear stress was measured by using oil-film interferometry (OFI). The single pixel procedure described in Ref. [3] and the SPIV software are used to cross-correlate particle images and to calculate the velocity fields [1].

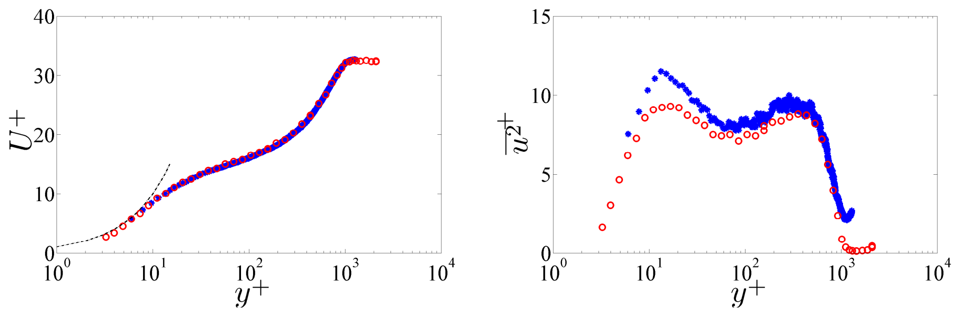

Figure 1. Inner-scaled profiles of the streamwise mean (left) and variance (right), at friction Reynolds number $Re_\tau = 1,000$ and $\beta \simeq 2.4$. Red points represent hotwire measurement and blue Single Pixel PIV measurement. Dashed line represents the viscous sublayer, given by $y^+ = U^+$.

References

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