STEREO-PIV MEASUREMENTS OF A TURBULENT BOUNDARY LAYER WITH A LARGE SPATIAL DYNAMIC RANGE: INFLUENCE OF THE FREE-STREAM TURBULENCE INTENSITY

S Herpin, J Soria, C Wong, M Stanislas

To cite this version:

S Herpin, J Soria, C Wong, M Stanislas. STEREO-PIV MEASUREMENTS OF A TURBULENT BOUNDARY LAYER WITH A LARGE SPATIAL DYNAMIC RANGE: INFLUENCE OF THE FREE-STREAM TURBULENCE INTENSITY. 22nd International Congress of Theoretical and Applied Mechanics (ICTAM2008), Aug 2008, Adelaide, Australia. hal-03123183

HAL Id: hal-03123183

https://hal-agrocampus-ouest.archives-ouvertes.fr/hal-03123183

Submitted on 27 Jan 2021

STEREO-PIV MEASUREMENTS OF A TURBULENT BOUNDARY LAYER WITH A LARGE SPATIAL DYNAMIC RANGE: INFLUENCE OF THE FREE-STREAM TURBULENCE INTENSITY

S.Herpin[1,2],J.Soria[2], C.Y. Wong[2], M.Stanislas[1],

1 : Laboratoire de Mecanique de Lille, Ecole Centrale de Lille, Bd Paul Langevin, Cite Scientifique, 59655 Villeneuve d'Ascq cedex, France

2 : Laboratory for Turbulence Research in Aerospace and Combustion, Department of Mechanical Engineering, MONASH university, VIC 3800 Australia

Summary Stereo-PIV measurements of a streamwise/wall-normal plane of a turbulent boundary layer at moderate Reynolds number were carried out in a water tunnel at two different conditions of free-stream turbulence intensity ($Tu_\infty = 5.5\%U_\infty$ and $Tu_\infty = 3\%U_\infty$). The experimental procedure involved the arrangement of 4 cameras with large CCD arrays in order to get enough spatial dynamic range to resolve most of the coherent structures in the flow. Some statistical results of the two datasets are analysed and compared.

FLOW UNDER INVESTIGATION

The experiments were conducted in the LTRAC water-tunnel (Monash university) at two different free-stream turbulence intensities : $Tu_\infty = 5.5\%U_\infty$ and $Tu_\infty = 3\%U_\infty$. The two corresponding datasets will be respectively refered to as $SPIV_{5\%}$ and $SPIV_{3\%}$. It was checked that, in both conditions, the nature of this turbulence in the free-stream remains isotropic. A sketch of the water-tunnel is shown in figure 1, and an extensive description of the facility can be found in Kostas (2002). The boundary layer under investigation develops on the floor of the test section, after being artificially tripped. The measurements are carried out 3.7m downstream of the tripping device, at the same free-stream mean velocity ($U_\infty = 0.425m/s$). The characteristics of the boundary layers of the 2 datasets are summarised in table 2. The differences in terms of thickness and Reynolds number can be explained by the sensitivity of the laminar/turbulent transition behind the tripping device to Tu_∞: this transition occurs earlier for $SPIV_{5\%}$ than for $SPIV_{3\%}$.

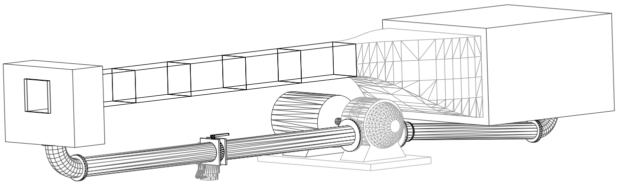

Figure 1. LTRAC water-tunnel

	δ	δ^+	R_θ
$SPIV_{3\%}$	30 mm	700	1300
$SPIV_{5\%}$	64mm	1360	2200

Figure 2. BL chracteristics
the superscript $^+$ denotes a scaling in wall units

EXPERIMENTAL PROCEDURE

The stereo PIV setup is arranged to measure a X-Y plane of the turbulent boundary layer. It actually consist of two stereo systems placed side by side, and whose field of view are just overlapping in the streamwise direction. This arrangement is shown in Figure 3, and a complete description of the experimental procedure can be found in Herpin et al (2007). Briefly, the large spatial dynamic range of the measurements was achieved thanks to the use of 4 cameras of type PCO 4000 with a large CCD array ($4008 * 2672$ pixels^2) and a rigorous experimental procedure to minimize the impact of the measurement noise on the resolution of the small scales. At the selected magnification (identical for $SPIV_{3\%}$ as for $SPIV_{5\%}$), the characteristics of the measurements are as shown in table 4. These characteristics provide a good spatial resolution of both the large scale coherent structures and the small vortices of the turbulent boundary layer.

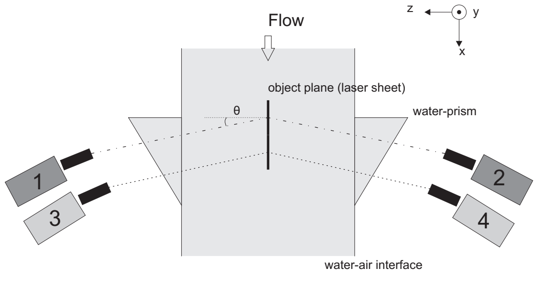

Figure 3. Top-view of the Stereo-PIV setup

	$SPIV_{3\%}$	$SPIV_{5\%}$
$[S_x; S_y]$	[140mm;47mm]	[165mm;47mm]
$[S_x; S_y]$	$[4.6\delta; 1.7\delta]$	$[2.6\delta; 0.75\delta]$
IW^+	14.7^+	13.6^+

Figure 4. Characteristics of the measurements
$[S_x; S_y]$ refers to the dimensions of the total field-of-view
IW refers to the interrogation window size

RESULTS

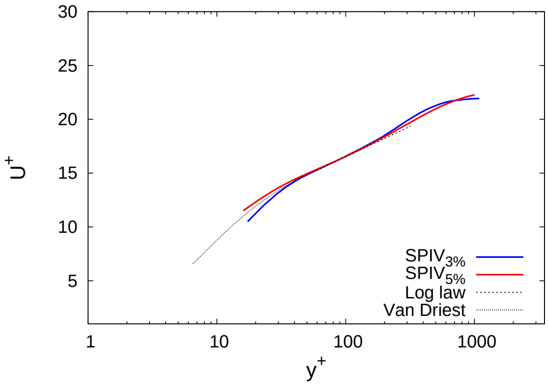

Figure 5. Mean streamwise velocity

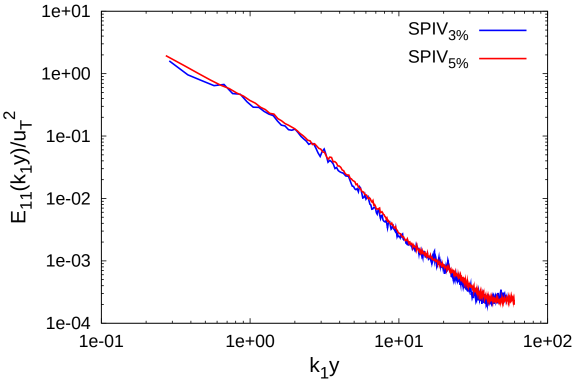

Figure 6. Longitudinal spectra of streamwise velocity at $y^+ = 100$

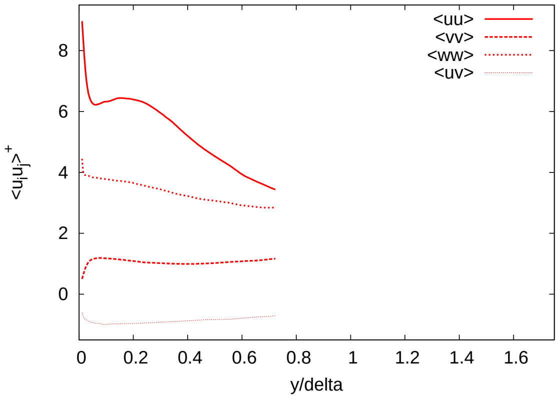

Figure 7. Profiles of Reynolds stresses for $SPIV_{5\%}$

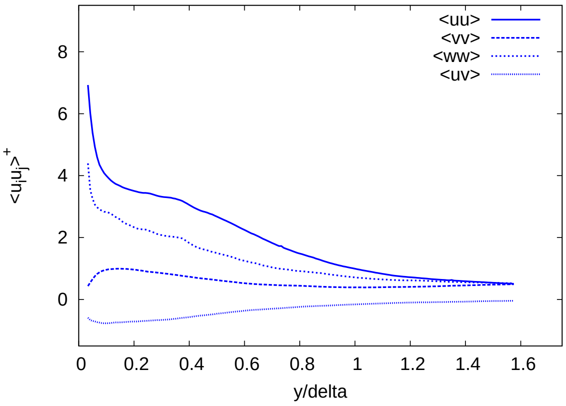

Figure 8. Profiles of Reynolds stresses for $SPIV_{3\%}$

The mean velocity profile, longitudinal power spectra, and Reynolds stresses are shown respectively on figures 5, 6, 7 and 8. The study of the mean velocity and Reynolds stresses profiles shows on the whole that the inner part of the boundary layer (buffer and logarithmic region) remains free from effects of Tu_∞. The peak of $< u'u' >$ in the buffer region appears stronger for $SPIV_{5\%}$ than for $SPIV_{3\%}$ but this is expected given the difference in Reynolds number (Hutchins and Marusic (2007)). Also, the influence of Tu_∞ is clearly visible in the outer region, as expected because of the intermittency. In figure 5, the 'strength of the wake' is weaker for $SPIV_{5\%}$ than for $SPIV_{3\%}$ (this trend cannot be explained by Reynolds number effects Erm (1988)). As for the Reynolds stresses in this region, the diagonal terms display higher values for $SPIV_{5\%}$ than for $SPIV_{3\%}$, while the production terms <uv> are comparable in both conditions. For $SPIV_{3\%}$, the full thickness of the boundary layer is measured, and it is possible to check on the Reynolds stresses profiles at the edge of the boundary layer that the turbulent motion is isotropic and that its intensity is consistent with Tu_∞. It is of great interest to note that the non-dimensional SPIV power spectra at $y^+ = 100$ are unaffected by Tu_∞ over the full range of wavenumbers. The spurious lift-up in the high wavenumber domain is typical of the measurement technique (Foucaut et al (2004)) and is due to the averaging effect over the interrogation window and to the PIV noise.

References

Erm L (1988) Low reynolds number turbulent boundary layers. PhD thesis, Melbourne Uni.

Foucaut JM, Carlier J, Stanislas M (2004) PIV optimization for the study of turbulent flow using spectral analysis. Meas Sci Technol 15

Herpin S, Wong CY, Stanislas M, Soria J (2007) High spatial resolution stereoscopic DPIV. Intl. Symp. on PIV, Rome, Italy

Hutchins N, Marusic I (2007) Evidence of very long meandering features in the logarithmic region of turbulent boundary layers. J Fluid Mech 579:1–28

Kostas J (2002) An experimental investigation of the structure of a turbulent backward facing step flow. PhD thesis, Monash Uni.