REYNOLDS-NUMBER SCALING OF JOINT-PDFS IN TURBULENT PIPE FLOW

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Wall-bounded turbulence is an extremely complex phenomenon, and despite constant progress in our understanding, the true nature of these flows is still not clear. In order to better understand this intrinsic three-dimensional process, it is important to measure and analyse different components of the velocity vector [1]. In order to contribute to our understanding, measurements of Reynolds-stress tensor components were obtained from a number of single-wire and X-wire thermal anemometry probes, covering a range of friction Reynolds number (Re_τ) of $6 \times 10^3 < Re_\tau < 3.8 \times 10^4$. These are part of the first measurement campaign performed in the Long Pipe facility of the CICLoPE Laboratory [2], which allows for fully resolved measurements of turbulent flows while using large aspect ratio traditional hot-wire sensors, with a minimized spatial filtering effect [3]. As previously reported in Ref. [4], the results of the present measurements provide strong support for the scaling of the Reynolds stress tensor predicted by the attached eddy hypothesis. In particular, the streamwise variance profile shows a clear logarithmic region, with a Townsend-Perry constant of $A_2 \approx 1.26$, quantitatively in agreeemenet with ONR/Superpipe measurements [5]. The wall-normal variance profile exhibits a Reynolds-number-independent plateau, while the spanwise component obeys to a logarithmic scaling over a much wider wall-normal distance than the streamwise component, with a slope that is nearly half of that of the Townsend-Perry constant, i.e. $A_{2,w} \approx A_2/2$.

In the present work, we further investigate the structure of the Reynolds-stress tensor via quadrant analysis [6] and the analysis of joint probability density functions of the streamwise and wall-normal components of velocity the fluctuations, u and v, respectively (see Fig. 1). Quadrant analysis has been widely used to understand the physics of the generation of the Reynolds-shear stresses [7]. This work focuses on Reynolds-number effects on quadrant-analysis, and in particular on the behaviour of extreme events that can be associated with sweeps or ejections, when the friction Reynolds number becomes very large. Furthermore, the contribution of these events to the total shear stress is analysed, showing how the contribution to the total Reynolds stresses in extreme events becomes increasingly important for increasing Reynolds number.

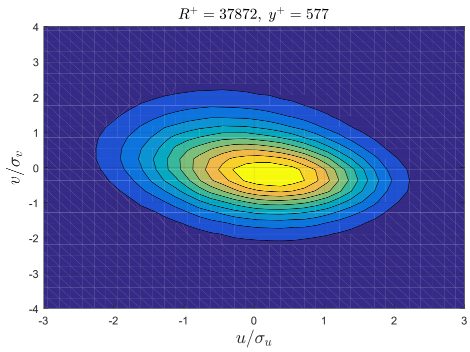

Figure 1. Joint pdf of streamwise and wall-normal velocity component for a friction Reynolds number $Re_\tau \approx 3.8 \times 10^4$ and a distance from the wall in viscous units of $y^+ \approx 570$.

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