3D LAGRANGIAN PARTICLE TRACKING WITH MULTI-PULSE SHAKE-THE-BOX IN TURBULENT BOUNDARY LAYER FLOWS AT HIGH REYNOLDS NUMBERS

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The recent introduction of the Multi-Pulse Shake-The-Box technique (MP-STB [3]) extended the capabilities of the Shake-The-Box (STB [4]) 3D Lagrangian particle tracking (LPT) algorithm in terms of applicable flow velocity. In particular, the MP-STB allows for 3D LPT investigations at velocities relevant for industrial and aerodynamic applications in relatively large volumes where the adoption of a time-resolved recording strategy would result in significant compromises in terms of spatial range or resolution (in order to limit the particle displacement between subsequent recordings). Multi-pulse sequences are obtained by synchronizing multiple illumination systems to generate bursts of laser pulses (typically four) where the time separation can be freely adjusted down to less than a microsecond (e.g. for supersonic applications). A 3D imaging system consisting of dual-frame cameras is adopted, where each frame is double-exposed to record the four pulses [2]; the MP-STB technique makes use of an iterative approach to overcome the limitations posed by the short observation time offered by the multi-pulse recording sequence, and allows for the reconstruction of individual four-pulse particle tracks in 3D [3]. The acquisition of long sequences of four-pulse recordings at low frequency ($10-15\,$Hz) enables the evaluation of flow statistics. In the present study, the MP-STB technique is employed for the investigation of turbulent boundary layer (TBL) flows at relatively high Reynolds numbers. A TBL at 15 m/s ($Re_\theta \approx 10,000$) is investigated in the SWG facility at DLR Göttingen; approximately $95,000$ individual tracks are reconstructed within the $80 \times 120 \times 10\,\mathrm{mm}^3$ domain for each four-pulse recording. Spatial gradients, as well as the instantaneous 3D pressure field, are evaluated by means of the FlowFit data assimilation algorithm [1] (fig.1-left). A TBL with adverse pressure gradient (APG) at 29 m/s ($Re_\theta \approx 30,000$) is investigated in the atmospheric wind tunnel of the University of Armed Forces in Munich; both planar PIV and MP-STB in a $80 \times 90 \times 7$ mm^3 domain are employed; the direct comparison of the results in terms of turbulent fluctuations (fig.1-right) highlights the higher spatial resolution of the LPT approach which, unlike PIV, does not suffer from the signal modulation caused by the finite size of the cross-correlation window. In the final presentation the MP-STB processing technique will be introduced together with the main parameters affecting its performances. Moreover, results regarding the TBL structure and flow statistics (e.g. TBL profiles, two-point correlations) will be presented.

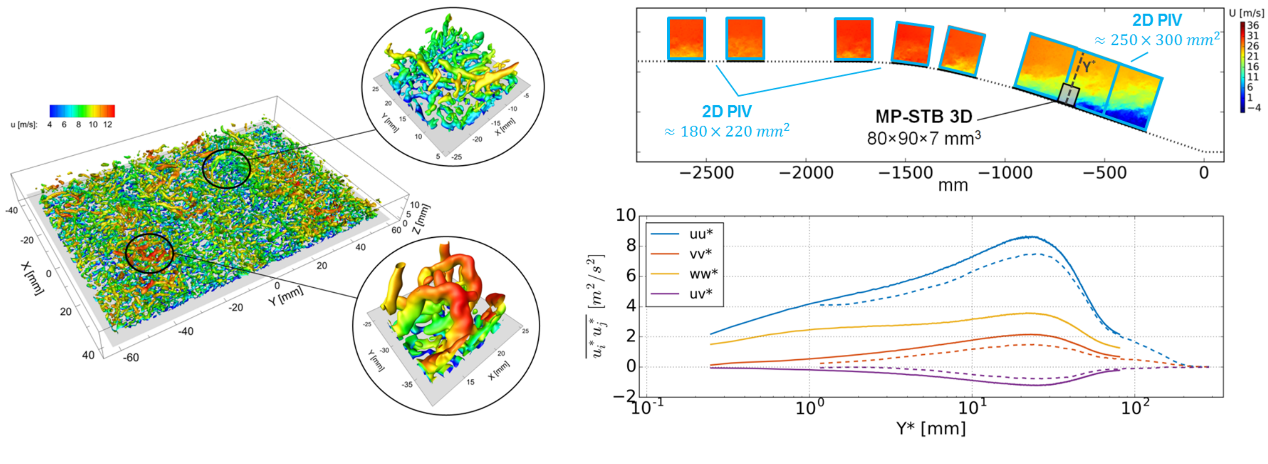

Figure 1. Left: TBL at 15 m/s; iso-surface of Q-criterion ($1,200,000$ 1/s^2) from FlowFit data assimilation algorithm applied to MP-STB tracking results, color-coded by the stream-wise velocity (X axis). Right: TBL with adverse pressure gradient at 29 m/s; profiles of Reynolds stresses along the wall-normal direction for PIV (dashed lines) and MP-STB (solid lines).

References

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