FLOW STRUCTURE DYNAMICS WITH EXTREME DISSIPATION EVENTS IN HOMOGENEOUS TURBULENCE – AN EXPERIMENTAL INVESTIGATION USING SHAKE-THE-BOX AND FLOWFIT

Andreas Schröder[1], Daniel Schanz[1], Sebastian Gesemann[1], Florian Huhn[1], Daniel Garaboa Paz[2] and Eberhard Bodenschatz[3]

[1] *Department of Experimental Methods, Institute of Aerodynamics and Flow Technology, German Aerospace Center, Göttingen, Germany.* andreas.schroeder@dlr.de

[2] *Group of Non-linear Physics, University of Santiago de Compostela, Spain.*

[3] *Laboratory for Fluid Dynamics, Pattern Formation and Biocomplexity, Max-Planck-Institute for Dynamics and Self-Organization, Göttingen, Germany*

Since the introduction of the Richardson-Kolmogorov cascade a picture of turbulence has been created that intrinsically connects a (in general) directional down-scaling process featuring vortical flow structures with the overall energy transfer finally ending into viscous dissipation at the smallest scales of the cascade. In turbulent flows at sufficient Reynolds number intermittency of extreme dissipation events is accompanied by strong enstrophy events and both have a close relationship to the pressure Laplacian. The aim of the present investigation is to analyze the temporal dynamics of flow structures generating extreme dissipation events. Conditional ensemble averages and Lagrangian viewpoints shall complement this topological study.

We present measurements of the full velocity gradient tensor and all elements of the dissipation rate based on dense fields of fluid particle trajectories in homogeneous turbulence at Re_λ~270 and ~370 in a von Kármán flow between two counter-rotating propellers. Applying the *Shake-The-Box* (STB) particle tracking algorithm [1], we are able to instantaneously track up to ~100.000 particles in a measurement volume of 50 x 50 x 15 mm³. The mean inter-particle distance is lower than 7 Kolmogorov lengths. The data assimilation scheme *FlowFit* [2] with continuity and Navier-Stokes- constraints is used to interpolate the scattered velocity and acceleration data by continuous 3D B-Splines in a cubic grid, enabling to recover (locally) the smallest flow scales. We compute the energy dissipation rate directly by using local velocity gradient information gained by FlowFit at midpoints of particle tetrahedra in close proximity of a few Kolmogorov lengths and compare it to known inertial range approaches using two-point statistics.

The experimental setup at the GTF3 of MPI-DS in Göttingen consists of a cylindrical water tank (500 mm diameter) with two counter-rotating propellers at the top and at the bottom, generating a von Kármán flow with a homogeneous turbulent region in the center (at least in radial directions). From earlier experiments [5], the expected Kolmogorov length for the lower Re_λ is $\eta \sim 100\,\mu$m at a propeller frequency of 0.5 Hz. The Kolmogorov time is $\tau \sim 10$ ms, i.e., temporal oversampling by a factor of 12.5 at 1.25 kHz frame rate. Spherical monodisperse and nearly neutrally buoyant polystyrene particles (20μm diameter) are illuminated by a fibre-coupled 150 W Nd:YAG high frequency laser (IB Chronos 400 MM IC SHG) in the center of the tank. Four CMOS cameras (Phantom v640, 2560 x 1600 pixel, 1250 Hz) equipped with 100 mm Zeiss macro lenses ($f_\#$ = 16) and Scheimpflug adapters record the particles in ~45° forward scattering. Prisms attached to the tank avoid astigmatism of particle images.

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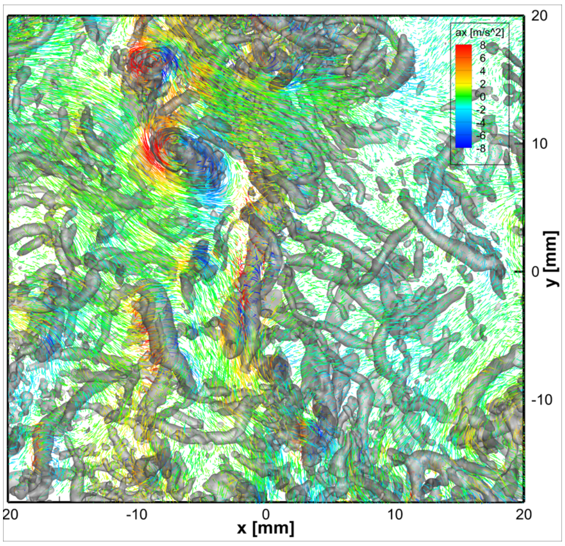

Figure 1. Dense Lagrangian particle tracks measured by STB, color coded by x-component of acceleration and iso-surfaces of Q-criterion, Q= 2500 s^{-2} from FlowFit. $Re_\lambda \sim 270$, Kármán flow at GTF3 at MPI-

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