

Experiments on Very Large Structures in Fully Developed Pipe Flow

Summary

The running phase of the project aims at investigating turbulent pipe flow at high Reynolds numbers. Over decades, there have been increasing interests to better understand turbulent coherent structures, forming the Large and Very Large Scale Motions, LSM and VLSM, respectively. Nevertheless, a solid definition of their nature and evolution is still incomplete. Therefore, the current project focuses on clarifying the nature and origin of the LSM and VLSM as well as describing and identifying them in quantitative manner. To this end, experiments and numerical computations together with partners within the SPP are to be performed and matched closely as possible. Experiments at Cottbus Large Pipe Test Facility (CoLa-Pipe), which was used successfully along the first phase, will be conducted at bulk Reynolds numbers of $6 \times 10^4 \leq Re_b \leq 1 \times 10^6$, based on pipe diameter (D) and the bulk velocity (U_b), and for Mach numbers $Ma < 0.23$. Turbulent flow properties are to be measured using miniaturized Hot Wire Anemometry (HWA), high speed Particle Image Velocimetry (H-S PIV) and Shake The Box (STB) particle tracking technique in collaboration with DLR (A. Schröder).

Two prominent objectives are targeted. Both objectives are based on our findings along the first phase of this study and they will enrich our knowledge about turbulent coherent structures using advanced measurement techniques that provide higher spatial and temporal resolutions. The first goal is to clarify uncertainties concerning scaling of the structural turbulence properties using miniaturized HWA, H-S PIV, and 3D high-resolution profile measurements.

The second goal is to quantify the kinematics and dynamics of the large-scale coherent structures. The length scales, energy contents and wall-normal locations of such structures have been addressed in pre-multiplied energy spectra during the first phase of this study. Throughout the second phase, we will extract low order subspaces of highly dimensional turbulent flows, from 2D and 3D time-resolved measurements on a moving frame of reference by applying a Characteristic DMD in collaboration with University of Bayreuth (J. Sesterhenn). Optimized combinations of extracted subspaces with long life times will form reduced order models, which accommodate structures that are known to be responsible for the formation of the spectral peaks. Life times and spatio-temporal evolutions of each group of structures will be studied in absence of small-scale structures. Using this approach, we will determine how each group of structures with certain length scales, contribute to turbulence properties such as turbulent kinetic energy budgets, Reynolds stresses and viscous shear stress.

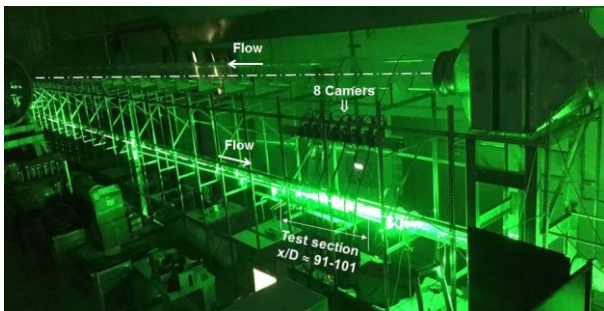


Figure: The CoLa-Pipe facility with the Particle Image Velocimetry (PIV) optical setup.

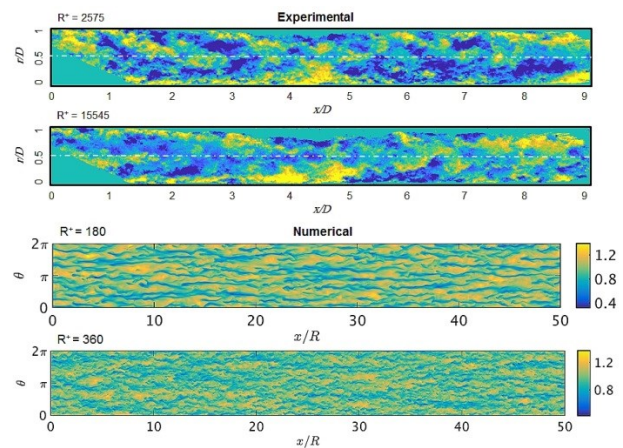


Figure: Streamwise velocity component normalized by bulk velocity from experiment, and DNS at radial location of $r/R = 0.85$.