PIV applied to strongly inhomogeneous turbulence

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One of the unique features of PIV is that it is capable of measuring the instantaneous vorticity field of a flow. In early applications of PIV only one component of the vorticity vector can be measured in a plane, while In modern implementations of PIV, such as multiplane PIV and tomographic PIV, it is possible to obtain the volumetric and time-resolved vorticity field. Given this capability, PIV is capable of providing flow data that cannot be obtained by any other measurement method. This has led to new findings and new insights in understanding the physics of turbulent flows. Of particular interest are strongly inhomogeneous turbulent flows, such as laminar-turbulent transition in pipe flow and the turbulent/non-turbulent interface in free-shear flows. In this contribution to the Symposium it is reviewed how PIV has provided new insights in these classical flow problems, and in particular how PIV has been untilized to obtain flow data that cannot be obtained otherwise with other experimental methods.

In the case of pipe flow, stereoscopic PIV records the fluid motion in a plane normal to the pipe axis. Using high-speed image recording and utilizing Taylor's hypothesis, it is possible to record the quasi-instantaneous fluid motion of flow structures that advect passed the measurement plane. This provides a detailed information on the instantaneous flow structures. This has led to the experimental observation of new solutions to the Navier-Stokes equations, and provided a basis for understanding the transition to turbulence in pipe flow. However, subsequent research showed that the transition to turbulence remains elusive.

For free-shear turbulent flows, irrotational fluid encloses the turbulent domain, where the interface between the turbulent and irrotational regions is very sharp. The propagation of the turbulent flow region into the irrotational flow domain, where irrotational fluid is being entrained in the turbulent domain, has been investigated for many years. PIV has made it possible to provide detailed and accurate measurements of the fluid motion relative to the interface. This has demonstrated that the fluid motion in the vicinity of the interface is a small-scale viscous process. This is contrary to the previous thought that entrainment would be a large-scale inertial process. It was thus possible for the first time to confirm ideas formuleted 50 years ago, and to quantitatively investigate the entrainment process by experimental methods.

In conclusion, PIV has demonstrated its value in providing new insights in the physics of turbulent flows.