Experiments in high Reynolds number pipe flow – facility and measurement

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Abstract

To clarify the universality in wall-bounded turbulence, experiments under high Reynolds number conditions, where the effects of viscosity can be neglected, are one of the key tools. However, conducting such experiments for turbulence research presents significant challenges. In the case of pipe flow using water, achieving high Reynolds numbers requires either high flow rates, large diameters, or controlling viscosity by increasing temperature, making it unavoidable to scale up the equipment. Moreover, there are numerous factors to consider, such as highly controlled flow and fluid temperature, ensuring fully developed flow through long straight pipes, minimizing surface roughness, and reducing deviations in inner diameter. The most critical issue is the spatial resolution of the velocity measurements. As Reynolds number increases, the viscous length scale decreases, requiring higher spatial resolution in the measurement devices. However, due to the physical limitation, achieving such high resolution makes it exceedingly difficult to obtain satisfactory results.

Since around 2000, high Reynolds number experiments conducted in Superpipe at Princeton University have gained attention, and subsequent experimental results in pipe flow and turbulent boundary layers have been reported. While these studies have provided numerous insights, debates about the reliability of experimental data—particularly concerning basic statistical quantities like pipe friction factors and mean velocity profiles－are still ongoing. These discussions are directly linked to the aforementioned challenges of high Reynolds number experiments.

In this presentation, the “High Reynolds Number Actual Flow Facility” (Hi-Reff) developed by the presenter is first introduced. It allows for friction Reynolds numbers on the order of 10^5. This facility not only achieves high Reynolds numbers but also be enables highly accurate flowrate measurements, which contribute to improving the precision of various experimental results. Next, the measured results of pipe friction, mean velocity profiles, and the 3-component turbulence intensity profiles obtained from this facility, are presented along with an evaluation of their validity. The measurements were conducted using highly validated Laser Doppler Velocimetry (LDV). Lastly, I will discuss the relationship between these profiles and the Attached Eddy Hypothesis.