Development of a spatial resolution correction method for achieving high precision in laser Doppler velocimetry

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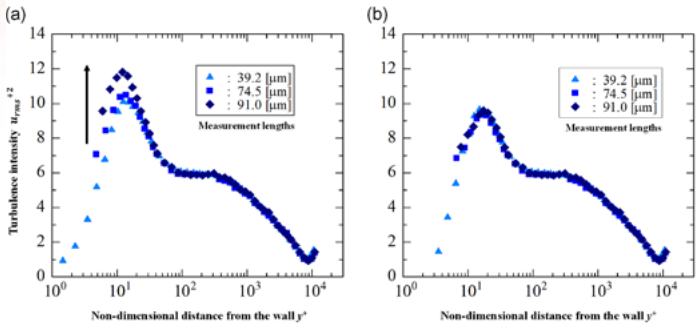
Various fluids are transported through pipelines, from residential to industrial scales. Understanding flow conditions in pipelines is important for enhancing safety and reducing energy consumption. However, for the large flow rates (or high Reynolds numbers) observed in large-scale manufacturing and power plants, the basic flow characteristics remain unclear because of insufficient experimental facilities and measurement difficulties. In such flow fields, accurate measurement of the velocity profile in a pipe is important for understanding the flow characteristics. Laser Doppler velocimetry (LDV), which is a noninvasive velocity measurement method, is useful for liquid flow. However, in large-flow-rate fields, the spatial resolution issue from the measurement volume of the LDV system significantly affects the measurements of the mean velocity and turbulence intensity, which represents the root-mean-squared (RMS) value of the velocity.

We measured the velocities in pipe flow using an LDV system at a national standard facility for large water-flow rates and evaluated the spatial resolution effect. The length of the measurement volume that directly affects the measurement values is defined as the “measurement length,” and the flow velocities were measured at different measurement lengths. The results show that the turbulence intensity near the wall increased with the measurement length, as shown in Figure (a). An accurate measurement length, crucial for correction, was determined using a wire rotary calibration device for the LDV system as a new approach. By applying the correction method to the measured measurement length and velocity gradient, the corrected turbulence intensity profiles with three different measurement lengths were consistent, as shown in Figure (b). In future work, we plan to validate the developed correction method through collaborative research with Physikalisch-Technische Bundesanstalt (PTB), Germany.



Velocity RMS values at each position in pipe flow: (a) Measured RMS, (b) corrected RMS

Reference**:** M. Ono et al., *Phys. Fluids* **34**, 045103, 2022, https://doi.org/10.1063/5.0084863