

Simultaneous measurement of temperature and velocity using cross-correlation μ PIVPramod Chamrathy¹, Steven T. Wereley¹, Suresh V. Garimella¹

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Cross correlation μ PIV analysis was used to simultaneously measure the temperature and velocity of a fluid in a channel flow. Peak broadening of the Correlation function due to the Brownian motion of the seed particles is used to measure the temperature of the fluid. In the presence of a non-uniform velocity, the broadening caused by the velocity gradients is subtracted from the total measured peak broadening to obtain temperature information.

1. Theory of PIV based Thermometry

The broadening of the cross correlation function due to Brownian motion is given by Equation 1, where $\langle s^2 \rangle$ is the mean square Brownian displacement, $S_{o,c}$ is the peak width of the cross correlation function, $S_{o,a}$ is the peak width of the auto correlation function, M is the magnification, k is the Boltzman constant, Δt is the time difference, d_p is the particle size, T is the temperature and μ is the viscosity of the fluid.

$$\langle s^2 \rangle = \frac{\Delta S_{o,c}^2 - \Delta S_{o,a}^2}{8M^2} = \frac{2k\Delta t}{3\pi d_p} \frac{T}{\mu} \quad (1)$$

In the presence of a non-uniform velocity, the gradient present in each interrogation window also contributes to the increase in the correlation peak width. By knowing the velocity field, the broadening due to velocity gradient can be calculated and subtracted from the total broadening to obtain the broadening due to Brownian motion.

2. Results and Conclusion

The peak-width increase in the x and y directions are uncoupled and can be measured independently by fitting a 2D Gaussian function to the correlation peak. The peak-width increase measured in the y direction is plotted in Figure 1 and can be seen to be quite uniform across the channel. The total peak width increase measured in the x direction and the corrected profiles are plotted in Figure 2. It can be seen that the peak-width increase is greater near the walls and lesser near the center of the channel as expected. The mean temperatures measured using the PIV technique were found to be offset from the expected values by a constant value, indicating a bias in the measurement technique. By comparing the measured and the expected values, a calibration constant of 0.75 was obtained. The calibrated values were plotted against the expected temperatures in Figure 3. The average absolute difference between the predicted and PIV measured temperatures was $\pm 1.5^\circ\text{C}$.

3. References

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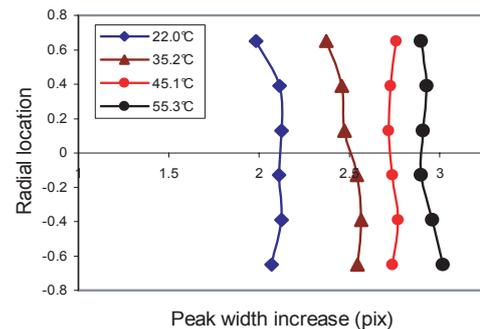


Figure 1: Peak-width increase in the y direction for different temperatures as a function of radial location.

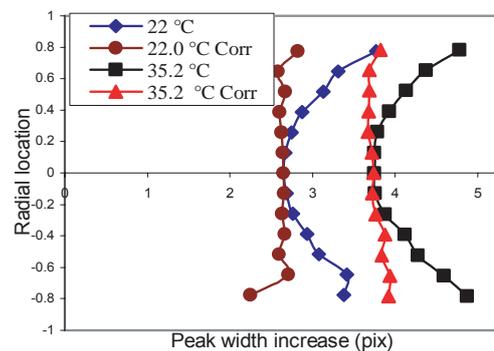


Fig. 2 Total peak-width increase in the x direction and the corrected peak-width increase for different temperatures as a function of radial location.

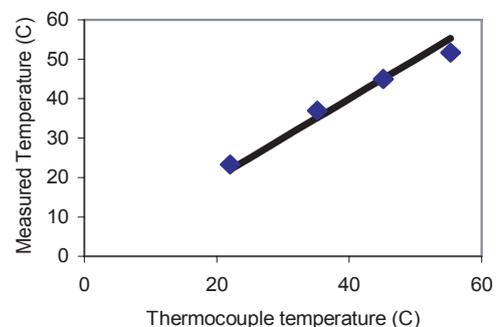


Fig. 3 Temperatures measured using Brownian motion plotted against the thermocouple temperatures. The average difference was $\pm 1.5^\circ\text{C}$.