Baseline measurements for testing of improved triple-sensor hotwire anemometer probe in a momentum conserving turbulent round jet

F. Gökhan Ergin, CTA Product Manager, Dantec Dynamics, Copenhagen, Denmark. gokhan.ergin@dantecdynamics.com
Clara M. Velte, Dept. Mechanical Engineering, Technical University of Denmark, Kgs. Lyngby, Denmark. cmve@dtu.dk

Experiments

Figure 1 Jet facility, hot-wire probe and 3-axis traversing mechanism.

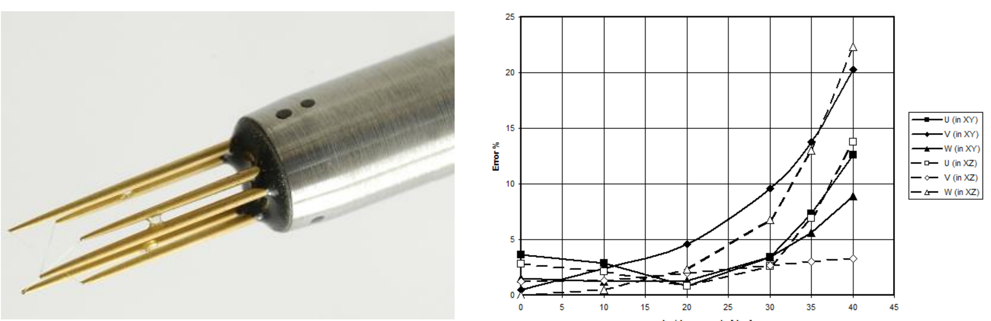

Figure 2 Left: New triple-sensor probe with straight prongs. Right: Error variation with incidence angle.

Three-component velocity measurements have been performed in a momentum conserving turbulent round jet (Fig. 1) using a CTA system and a new triple-sensor probe featuring straight prongs (Fig. 2L). The objective is to test the reliability of the new probe in a classical canonical flow that lends itself well to testing physical quantities such as momentum flux conservation as well as comparing directly to baseline data. The probe is positioned in excess of 2500 positions in each measurement plane using a computer controlled traversing mechanism (Fig. 1). A conventional two-step calibration is performed where the directional calibration is conducted following a velocity calibration. The calculated pitch and yaw factors are compared to expected values for similar probes reported in the literature (Tab. 1). An error analysis is performed using the pitch / yaw - roll mechanism in order to identify the acceptance angle for the probe for the data reduction scheme (Fig. 2R).

Measured	k^2	h^2
Wire 1	0,0112	1,0092
Wire 2	0,0395	1,0180
Wire 3	0,0226	1,0327
Expected	0,025	1,04

Table 1 Measured directional calibration constants.

Streamwise velocity

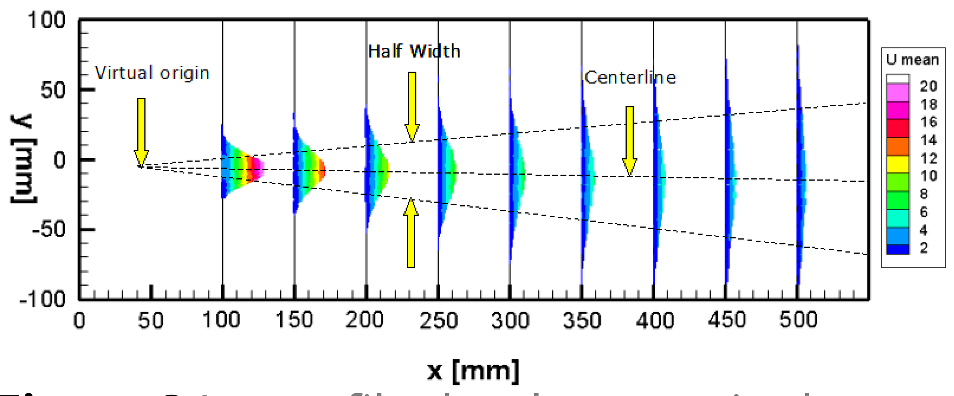

Figure 3 Jet profile development in down-stream direction x. Nozzle located at (0;0)

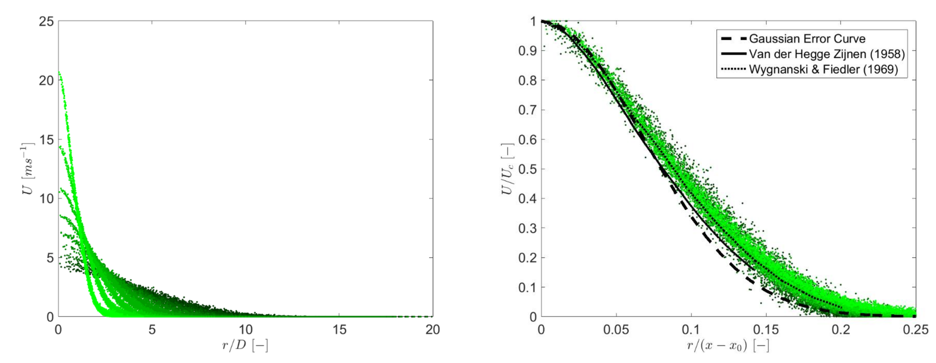

Figure 4 Unscaled (left) and similarity scaled (right) streamwise velocity (U) profiles.

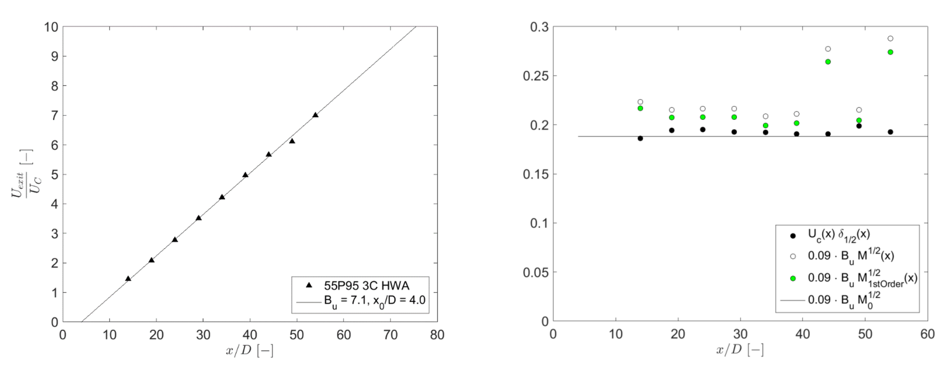

Figure 5 Left: Centerline velocity change in *x*. Right: Momentum flux conservation in *x*.

The measurements capture the main well-known characteristics of the round jet such as the jet centerline, jet half width, and virtual origin (Fig. 3). The stream wise velocity profiles at each downstream position were plotted in regular and similarity scaling variables, displaying clear similarity collapse of the mean velocity even as far upstream as x/D=10 (Fig. 4). Due to the turbulence dependency upon initial conditions, the profile could not be quantitatively validated against other jet measurements, although it was seen that the measurements in general displayed the expected trends. The jet expansion and centreline velocity developments were determined from the data and a multiple check of the momentum flux conservation was performed (Fig. 5). The results indicate a general agreement, even though some spurious points existed that were hypothesized to stem from the differences in measurement plane extent.

Power Spectra

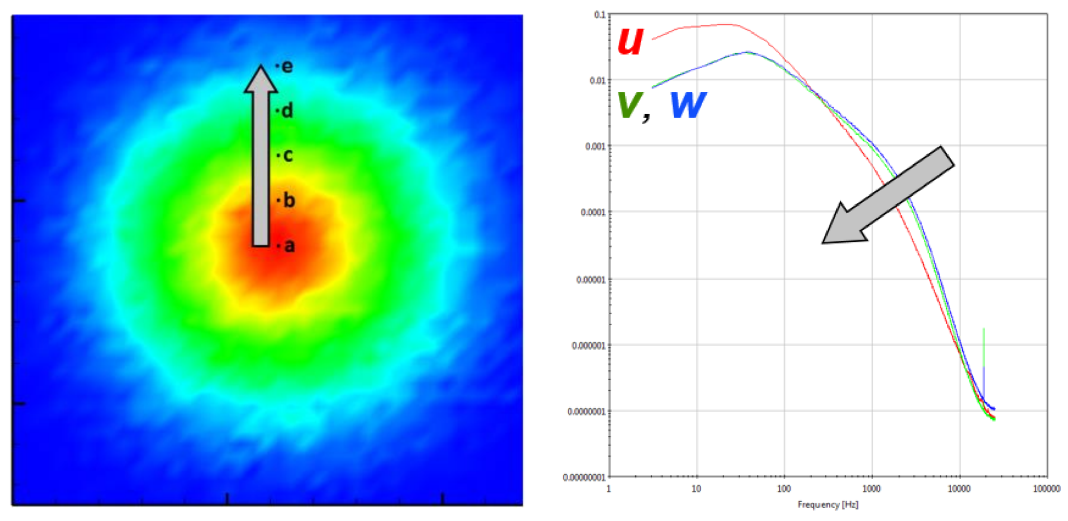

Figure 6 Left: PSD computation positions at *x*=30D. Right: Power spectra for *u*, *v*, and *w* at 30D on the jet centerline. Arrow on the right indicates the movement of PSD results as the measurement point moves from a to e.

Power spectra were measured at 30 diameters downstream of the jet exit on the centerline, quarter-width, half-width, three-quarters width and at full jet width, demonstrating the variations in the dynamic statistical moments (Fig. 6L). The measured power spectra capture the expected characteristics even at large distances from the jet centreline where the turbulence intensity is exceptionally high (Fig. 6R).

Conclusions & Future work

The new probe design produces accurate directional calibrations by eliminating the prong effects observed in previous designs. As a direct result of this, the reconstructed 3D velocity vector is more accurate within the acceptance cone of the probe – approximately 60° for the current prong configuration and data reduction scheme. Future work includes (i) the comparison of different directional calibration schemes for reduced error over a larger acceptance angle. (ii) The PSD spectra will be compared to high-precision Laser Doppler Anemometer (LDA) power spectra for validation of the novel hotwire probe design. (iii) Further, static moments such as mean velocity, rms values etc. measured with the novel hot-wire probe will be compared to corresponding LDA measurements in the same jet facility. In particular, the comparison will focus on the challenging case of high turbulence intensity in the outer parts of the jet where hot-wire probes have classically had significant difficulties in producing reliable results.