the 70% porous glass fiber screen performed best. The roughness of the screen affected the velocity field but had little effect on the temperature field because of the turbulent boundary layer. More details are provided in the references.[2,3] The screen was removed when velocity measurements were made with a hot-wire anemometer.

We have been investigating the heated-wire technique. The difficulty is that the flowfield of interest involves mixed convection with buoyant flow near the jet edges. However, the technique is of great interest. We appreciate the experience and recommendations of Gartenberg and Roberts.

References

[1]Gartenberg, E., and Roberts, A. S., Jr., "Comment on 'Infrared Imaging of Large-Amplitude, Low-Frequency Disturbances on a Planar Jet,'" *AIAA Journal*, Vol. 33, No. 3, 1995, p. 568.

[2]Stetz, M., "Characterizing Cold Air Jets and Diffuser Performance via Infrared Thermography," M.S. Thesis, Colorado State Univ., Boulder, CO, 1993.

[3]Hassani, V. A., and Stetz, M., "Application of Infrared Thermography to Room Air Temperature Measurements," ASHRAE, Symposium Paper, OR-94-21-3, 1994.

Comment on "Wakes of Three Axisymmetric Bodies at Zero Angle of Attack"

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REFERENCE 1 recently presented flowfield data for the near-wake region of three axisymmetric bodies. Conventional hot-wire anemometry was used to measure the mean velocity and the rms velocity in the unsteady recirculating flow regions close to the bodies. Results were reported between 0.1 and 4 body diameters d downstream of the bodies. The "reported" local turbulence level u_2 on the wake centerline was larger than 50% from $0.1d$ to $1.5d$ with peak intensities exceeding 100% (Fig. 4 of Ref. 1).

A well-known limitation of conventional hot-wire anemometry is its directional ambiguity. As stated by Eaton and Johnston,[2] "hot-wire anemometers are not suitable for use in reversing flows." A systematic error is introduced into a measurement whenever differences exist between conditions of measurement and of calibration. Except for the dynamic calibration technique described by Perry,[3] hot wires are usually calibrated in a steady flow with a known direction. It would be overly optimistic to expect that the heat transfer process for the hot wire (and thus the calibration law) would remain the same if the calibrated wire were to be placed in an unsteady flow with a reversing direction. The flying hot-wire technique,[3] pulsed-wire anemometry,[9] the tandem hot-wire technique,[10] or directionally sensitive laser Doppler anemometry (LDA) must be used in such flows.

Simpson[4] compares hot-film and laser anemometer measurements performed in a separating boundary layer where the fraction of time the flow moved in the downstream direction (γ_p) was measured (by the laser anemometer). The data of Simpson[4] show that the mean velocity and the rms velocity measured by the hot film are appreciably different from the laser anemometer results for $\gamma_p < 0.80$ and $\gamma_p < 0.95$, respectively. Based on this, Simpson and Chew[5] conclude that "directionally ambigous hot-wire anemometry techniques should not be used in separated flow regions."

Rodi[6] states that conventional hot-wire anemometry is applicable to flows with low turbulence levels (say, lower than 25%). Special methods of analyzing hot-wire signals must be employed to separate the mean and the rms velocity components in highly turbulent flows.[6] Freymuth[7] shows that the error due to large turbulence fluctuations can be minimized when a linearizer is used in constant-temperature hot-wire anemometry together with optimally adjusted broadband amplifiers. However, Perry[3] notes that a linearizer eliminates only heat transfer nonlinearities and leaves out nonlinearities caused by cross flow velocity components. The analysis of Perry[3] shows that errors in u_2 can be as high as 18% for the linearized and 35% for the nonlinearized hot-wire outputs when u_2 is 100%. These error values are specified for flows with a known mean flow direction. In an unsteady reversing flow such as the one studied in Ref. 1, errors due to nonlinear effects are not known.

Reference 1 states that "accuracies" of the hot-wire anemometer outputs for the mean velocity and fluctuations are about ± 0.1 and ± 0.002 m/s (for a free stream velocity of 10 m/s). Authors of Ref. 1 have apparently used the term "accuracy" mistakenly to describe what was really the "precision" of the anemometer. The distinction between the two concepts is very important in engineering studies. According to Holman and Gajda,[8] the accuracy of an instrument indicates deviation of its reading from a known input, whereas the precision of an instrument indicates its ability to reproduce a certain reading. Accuracy can only be exactly determined when the value of the measured quantity is known. To reasonably estimate the accuracy of conventional hot-wire anemometry for the flowfields of Ref. 1, independent measurements using either a directionally sensitive hot-wire technique or LDA would have been necessary.

Upon reading Ref. 1, novice researchers in the field of experimental fluid dynamics might be led into believing that "it is permissible to use conventional hot-wire anemometry in recirculating flow regions," particularly since the practice had been reported previously (Refs. 4, 5, and 6 of Ref. 1) in spite of the earlier warnings by Simpson[4] and others, e.g., Refs. 2 and 3. In their desire to advance frontiers of knowledge, experimentalists often use instruments at their capability limits. However, these limits must be known and instruments should not be used when measurement conditions violate their principles of operation. It is well accepted in the scientific community that conventional hot-wire anemometry should not be used to measure mean and rms velocities in turbulent separated flow regions. The authors should have restricted their results to those regions downstream of the reversed flow region where it was known that the criteria established by Simpson[4] were satisfied.

References

[1]Ilday, Ö., Acar, H., Elbay, M. K., and Atli, V., "Wakes of Three Axisymmetric Bodies at Zero Angle of Attack," *AIAA Journal*, Vol. 31, No. 6, 1993, pp. 1152–1154.

[2]Eaton, J. K., and Johnston, J. P., "A Review of Research on Subsonic Turbulent Flow Reattachment," *AIAA Journal*, Vol. 19, No. 9, 1981, pp. 1093–1100.

[3]Perry, A. E., *Hot-Wire Anemometry*, Oxford Univ. Press, New York, 1982, pp. 121 and 131.

[4]Simpson, R. L., "Interpreting Laser and Hot-Film Anemometer Signals in a Separating Boundary-Layer," *AIAA Journal*, Vol. 14, No. 1, 1976, pp. 124–126.

[5]Simpson, R. L., and Chew, Y. T., "Measurements in Steady and Unsteady Separated Turbulent Boundary-Layers," Invited Paper, Third International Workshop on Laser Velocimetry, Purdue Univ., West Lafayette, IN, July 1978; see also *Laser Velocimetry and Particle Sizing*, Hemisphere, New York, 1979.

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[6]Rodi, W., "A New Method of Analyzing Hot-Wire Signals in Highly Turbulent Flow and Its Evaluation in a Round Jet," DISA Information, No. 17, 1975, pp. 9–18.

[7]Freymuth, P., "Further Investigation of the Non-Linear Theory for Constant-Temperature Hot-Wire Anemometers," *Journal of Physics E*, Vol. 10, 1977, pp. 710–713.

[8]Holman, J. P., and Gajda, W. J., *Experimental Methods for Engineers*, McGraw-Hill, New York, 1978, pp. 7, 8.

[9]Hanford, P. M., and Bradshaw, P., "The Pulsed-Wire Anemometer," *Experiments in Fluids*, Vol. 7, 1989, pp. 125–132.

[10]Tanaka, E., Inoue, Y., and Yamashita, S., "An Experimental Study on the Two-Dimensional Opposed Wall Jet in a Turbulent Boundary-Layer," *Experiments in Fluids*, Vol. 17, 1994, pp. 238–245.

Reply by the Authors to O. Özcan, D. A. Johnson, and R. L. Simpson

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A TIME-AVERAGED base flow has been considered in our paper[1] as had been done in some previous works.[2–5] It is well known that there are periodic phenomena associated with base flows of axisymmetric bodies, but these are not nearly predominant.[2] This consideration makes it relatively easy to obtain some information that is important for our engineering point of view.

Several works[2–5] in the literature employed the hot-wire technique in the separated flows. Despite the limitations and difficulties of this technique in these cases, it provides important information related to the general structure of the flowfield at least qualitatively.

In our paper[1] a correction has been made on the mean velocity output of CTA in the near-wake region to prevent high turbulence effects as explained in Ref. 6. The accuracy values for mean velocity and fluctuations have been obtained from our computerized measurements as deviations from expected values when the hot-wire probe is exposed to flow in the known flow conditions. Therefore, our paper does not confuse the term "accuracy" with the term "precision."

Our paper indicates the location of the rear-stagnation point and the location where the maximum rms values exist in the near-wake region. The paper also indicates the influence of the base geometry on these values and total drag. These data are important for engineering purposes. We hope these data are verified by other techniques in the future.

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References

[1]İlday, Ö., Acar, H., Elbay, M. K., and Atli, V., "Wakes of Three Axisymmetric Bodies at Zero Angle of Attack," *AIAA Journal*, Vol. 31, No. 6, 1993, pp. 1152–1154.

[2]Calvert, J. R., "Experiments on the Low-Speed Flow Past Cones," *Journal of Fluid Mechanics*, Vol. 27, Pt. 2, 1967, pp. 273–289.

[3]Merz, R. A., Yi, C. H., and Przirembel, C. E. G., "Turbulence Intensities in the Near-Wake of a Semielliptical Afterbody," *AIAA Journal*, Vol. 24, No. 12, 1986, pp. 2038–2040.

[4]Merz, R. A., Yi, C. H., and Przirembel, C. E. G., "The Subsonic Near-Wake of an Axisymmetric Semielliptical Afterbody," *AIAA Journal*, Vol. 23, No. 10, 1985, pp. 1512–1517.

[5]Sinha, S. N., Gupta, A. K., and Oberai, M. M., "Laminar Separating Flow over Backsteps and Cavities, Part I: Backsteps," *AIAA Journal*, Vol. 19, No. 12, 1981, pp. 1527–1530.

[6]Atli, V., "Subsonic Flow over a Two-Dimensional Obstacle Immersed in a Turbulent Boundary Layer on a Flat Surface," *Journal of Wind Engineering and Industrial Aerodynamics*, Vol. 13, Nos. 2–3, 1988, pp. 225–239.