Readers' Forum

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Comment on "Application of a Three-Sensor Hot-Wire Probe for Incompressible Flow"

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THE authors of Ref. 1 have presented a new method for the calibration and use of a three-sensor hot-wire or hot-film probe which offers, according to them, several advantages over existing methods, such as rapid and efficient processing of a large amount of data. They also claim that their method can accurately process data taken in flows with high turbulence intensities. Because the reader might get the wrong impression, I would like to add the following:

1) The linearization of the anemometry signals is the main contributor to the time required for hot-wire data processing (HWDP). In the present case, commercially available analog linearizers have been used. The financial cost to the experimentalist of the measurement system will be strongly influenced by the inclusion of these devices for each of the three sensors. Apart from that, such a linearizer may be quite inaccurate at high turbulence intensities and, at best, the signal-to-noise ratio will be only slightly degraded. In modern HWDP "linearization" is made digitally with the use of "look-up" tables allowing a fast conversion of the anemometer signals into velocity components.[2] This technique seems to be faster than using any algebraic relationship between the anemometer voltages and the velocity vector.

2) Qualification tests which can give confidence in the method have not been made. Instead, a comparison with LDV data has been made. This comparison may be inadequate and misleading, for the following reasons:

a) Only maximum values have been compared, not the whole profile.

b) Comparison between quite different experiments may be dangerous. We have recently seen the same experiments[3] made at different places give entirely different results. Scaling laws for turbulent wakes are not widely acceptable and choosing points with the same velocity ratio (0.80) for comparison, is rather inappropriate. The momentum thickness at the trailing edge could possibly be a length scale that could be used to find corresponding points in the two experiments.

3) The turbulence intensity of the flow that has been measured is rather low. Taking typical maximum values (-10 deg $\leq \alpha \leq 15$ deg and -5 deg $\leq \delta \leq 18$ deg) from their Fig. 8 for the pitch and yaw angles of the velocity vectors, it can be concluded that the turbulence intensities under which the method has been tested are rather low.

The best way to test any new measurement technique is to apply the technique in a well-established flow such as a channel flow[4] or pipe or boundary-layer flow.[5,6] By tilting and rotating the probe up to 30 deg the technique, or scheme, can be tested to severe yaw or pitch angles of the instaneous velocity vector, i.e., to an artificially high turbulence intensity.

References

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Reply by Authors to J. Andreopoulos

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THE authors would like to thank Dr. Andreopoulos for his review of our paper on the use of a three-sensor hot-wire or hot-film probe in incompressible flow. In response to his discussion, we would like to add the following comments.

This method was developed to acquire and process large amounts of velocity data taken between stages in a large scale axial flow research turbine. As was reported in Ref. 1, in order to adequately define the spatial and temporal variation of both the mean and turbulence velocity fields in this complex, unsteady, three-dimensional flow, it was necessary to obtain approximately 120 million measurements of the instantaneous velocity vector. The hot-wire data reduction techniques that were available during the planning of this

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experimental program were either too simplistic to yield accurate measurements in flows of unknown direction and high turbulence intensity or they required exceedingly complex solution procedures (i.e., iterative techniques) to obtain the instantaneous velocity vector, and as such precluded the cost effective reduction of such a large body of data. Our aim was to develop a method to reduce the linearized sensor outputs to an instantaneous velocity vector (engineering units) in an accurate and efficient manner.

With regard to linearization, during our experiments, this was performed on line. The three linearized sensor outputs were digitized using a high speed A-D converter and subsequently stored on magnetic tape. Each data realization, which consisted of linearization and analog-to-digital conversion, required less than one half millisecond, and as such presented no constraints relative to the time required to acquire data on a revolution-by-revolution basis and to spatially traverse the probe.

The major constraint was that of the computation and cost necessary to reduce the digitized linearized sensor outputs to a velocity vector. The authors were aware of no serious limitations concerning the use of analog linearizers in high turbulence flows.

The turbulence intensity of the flow that was been measured is, in general, not low. Figure 8 shows the unsteady, periodic

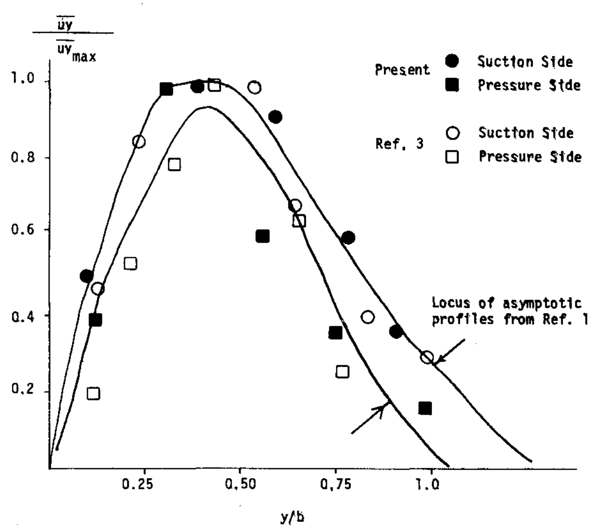

Fig. 1 Normalized Reynold shear stress profiles.

variation of the phase-locked ensemble-averaged velocity at the mean radius downstream of a rotating blade row. This figure contains no information about the level or distribution of turbulence in the flow at that location. In Ref. 1, it was shown that the turbulence intensities in the rotor blade wakes and secondary flow regions are quite large, on the order of 15-20%.

We do concede that rigorous qualification tests of the ability of the method to obtain accurate measurements of Reynolds stresses have not been demonstrated. We encourage any interested parties to perform such tests by yawing and pitching a probe in a flow of known turbulence stress distribution, as suggested by Dr. Andreopoulos, and reducing data using our technique. Our contention about the accuracy of the turbulence measurements is based partially on the accuracy with which the instantaneous velocity vector can be obtained, as evidence by the accuracy of the calibration data in our Fig. 6. Our comparison of the hot-wire data with the LDV data for an 80% mixed fully turbulent wake is probably more instructive than Dr. Andreopoulos suggests. A recent survey[2] of symmetric turbulent wake data indicates that by the time the wake has mixed to a 20% velocity deficit, it is approaching an asymptotic state where the influence of the upstream boundary layers is considerably diminished and the profiles of mean and turbulence velocities are self similar. For self-similar wake profiles, agreement of the maximum values of turbulent stress would imply agreement of the profile shapes. This is demonstrated in Fig. 1 herein, which shows the normalized shear stress profiles from both data sets compared with the locus of asymptotic stress profiles from data of Ref. 2. We realize that the two flows are not identical (i.e., two-dimensional vs three-dimensional); however, we feel that comparison of the turbulence stresses measured for each flow does give an indication of the accuracy of the proposed method.

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