Engineering Notes

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Measurement of Post-Separated Flowfields on Airfoils

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I. Introduction

MEASUREMENT of post separated flow fields on an airfoil is a very complicated problem. The principal difficulty involved is the proper choice of instrumentation, capable of detecting large flow inclinations in both pitch and yaw directions. Common methods such as pitot tube or boundary-layer mouse used with a surface pressure tap, are inadequate in separated flows. Hot wire and hot film probes are particularly good for the measurement of local velocity perturbations and can be used to resolve flow direction for small pitch and yaw angles, and laser velocimeters can detect and measure velocity fields with flow reversal. Unfortunately, neither of these instruments provide static pressure information. A comprehensive list of special pressure-measuring probes, their design and performance limitations are discussed in Ref. 1.

In a recent paper[2] it is reported that a simple modification of a basic three-tube probe, (two asymmetric chambered side tubes flanking a central total head tube) can be employed to measure the velocity and flow direction in separated flows. The probe is mounted to an indexed pitching mechanism, and is aligned with the local flow direction such that the pressure difference between the two outer tubes is zero. Local velocity and the flow direction in one plane can thus be determined. This setup and design appear attractive, but the system is not versatile, since it cannot measure local sidewash angles of the flow.

In order to overcome the above limitation, a rather small combination pitch-yaw probe was selected for the present research. Previous recommendations[1] against the use of this type probe, on the grounds that the probe tends to be bulky, were discounted after careful consideration. For separated flow measurements, the five tube probe is ideally suited because of its capability to provide pitch and yaw angle information as well as static and total pressures.

For measurements in flows with small inclinations in pitch and yaw, it is possible to determine flow direction and magnitude from the five pressure readings and linear calibration equations. For large flow angles, on the other hand, the calibration relations are nonlinear, and simultaneous determination of unknown pitch and yaw angles is not possible. One solution is to gimbal mount the probe and incorporate provisions for remote nulling in both pitch and yaw. An alternative approach, used in the present research, is to provide for nulling in one axis only and to utilize nonlinear calibration relations to determine flow direction with respect to the second axis. Preliminary calibration and results of earlier tests[3] have demonstrated the versatility and usefulness of this technique for scanning flows with large inclinations.

This Note deals with the description and calibration of the proble. Details of its application and results of post-separated velocity and pressure field measurements are reported in Ref. 4.

II. The Probe and the Scanning Mechanism

Figure 1 shows the five tube pitch-yaw pressure sensing probe. The tip geometry is based on the design of "AEROTECH" probe DC-120 #148.[5] The probe tip is fabricated from brass by turning the conical surfaces and precision boring the five (four direction sensing plus center pitot) pressure ports. Four stainless steel tubes of 0.032 in. outside diam are soldered to the tip pitch- and yaw-ports, and inserted within the outer 0.125 in. diam tube. This outer tube also serves as the center tap (total) pressure transmitting channel. The 0.125 in. tube is then fitted within larger tubes for increased stiffness. The stem is geared to a small drive motor which permits remote rotation of ±180° in yaw. This gear tain and drive motor are enclosed within a streamlined windshield to minimize aerodynamic interference.

With this mechanical arrangement, the drive motor is actuated until the side (yaw) pressure ports are nulled. Then local pitch angle and total and static pressure coefficients can be determined from the pressure difference between the vertical (pitch) ports, through appropriate calibration relationships. By appropriate coordinate transformations the local velocity vector can be resolved into components in any coordinate system. The entire apparatus is mounted on a track which permits remote traversing longitudinally and transversely. The resolutions of the linear and rotational position sensors are 0.015 in. and 0.38°, respectively.

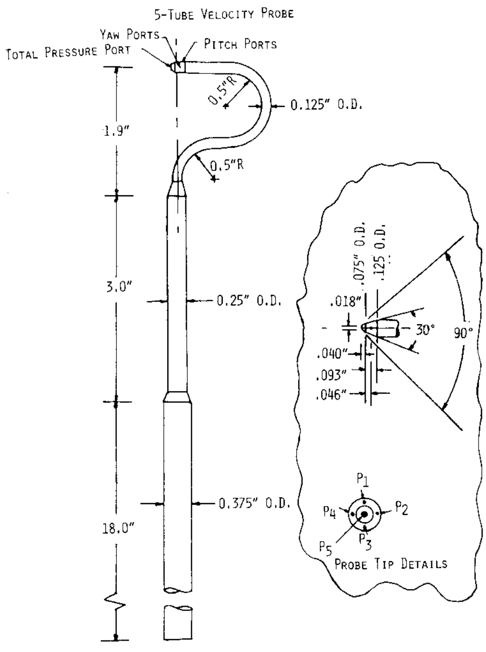

Fig. 1 The five-tube probe.

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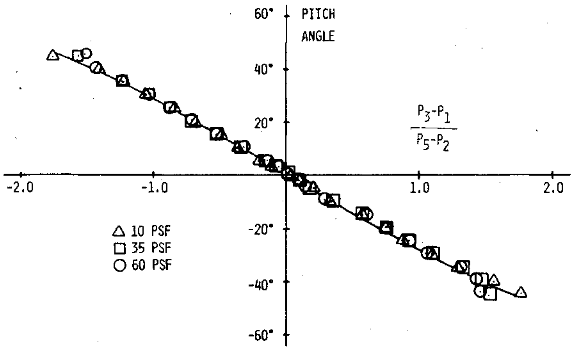

Fig. 2 Flow angularity calibration.

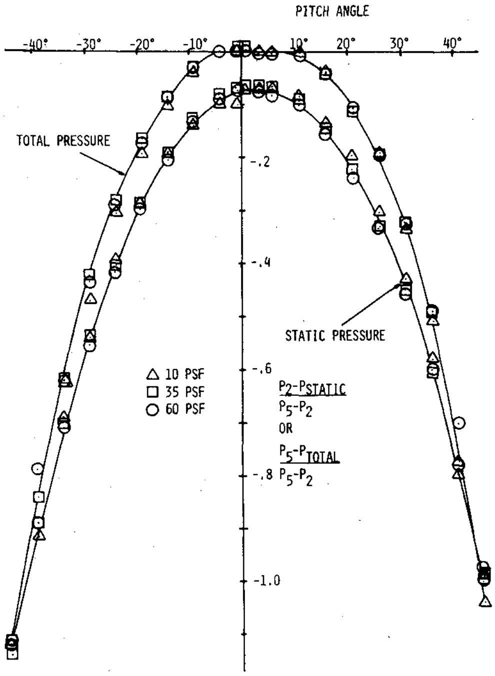

Fig. 3 Total and static pressure calibration.

III. Calibration Procedure and Results

Calibration of the five-tube probe was done in the Wichita State University low speed tunnel having a 7×10 ft test section. The probe was mounted to the test section floor in the horizontal position and the entire assembly rotated about the tunnel vertical axis. The five pressure readings were measured by transducers and recorded at every 5° interval in a ±45° range in pitch. In addition to the five pressures obtained from the probe, stream static and total pressure were also recorded. The results are plotted in Figs. 2 and 3. Figure 2 shows the variation of the pitch angle factor, $P_3 - P_1 / P_5 - P_2$ with the pitch angle. The calibration curve is very nearly linear up to ±35°. It then becomes nonlinear due to stalling of one of the pressure ports in the pitching plane. The static pressure and total pressure calibration curves (Fig. 3) exhibit a nonlinear trend.

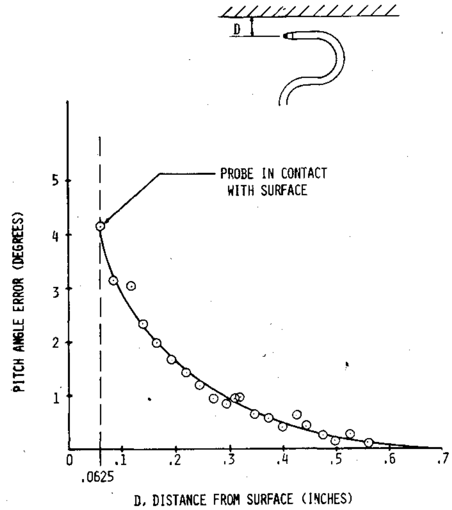

Fig. 4 Calibration for pitch angle correction.

Effects Dynamic Pressure and Support Interference

The probe was calibrated at three representative tunnel dynamic pressures of 10, 35, and 60 psf. Figures 2 and 3 illustrate that calibration is not affected by the changes in dynamic pressure.

Effects of windshield housing interference on the probe readings were also investigated with probe extensions of 16 in. and 10 in. The interference effect was found to be negligible.

Proximity Effects Due to the Wall

For probe positions within five probe diameters of a wall, proximity of the wall influences the probe readings and results in an error in the indicated local pitch angle of the velocity vector. Figure 4 shows the results of a calibration of this effect. The maximum error in the flow inclination is about 4°, when the probe is in contact with the surface. Appropriate corrections to the flow inclination for this effect have to be taken into account in the data reduction program.

Acknowledgment

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